AAF Technical Report 5142

TEST OF 1/3-SCALE POWERED MODEL OF CUSTER CHANNEL SHAPED WING FIVE-FOOT WIND-TUNNEL TEST NO. 487

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ARMY AIR FORCES

AIR MATERIEL COMMAND

Wright Field Dayton, Ohio

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PROCEDURE (cont'd)

Method No. 3. (Photographs 150245 to 150250). The model was set up similar to that of Method No. 1 except for the position with respect to the tunnel floor which was the same as that for method No. 2. This was done in order to determine the difference in lift on the channel wing due to being raised in the tunnel approximately 10 inches. The angle of attack was zero degrees, and the propeller clearances used were 3/16 and 7/16 inch. The pulley ratio was 1.87. The test procedure was the same as that described for Method No. 1.

With no power supplied to the wind tunnel, the airspeed in the tunnel upstream of the model was 16.8 mph when the propeller of the model was rotating at 3150 rpm. (Pulley ratio 1.87). For this reason, a set-up was made outside the tunnel. The whole assembly was placed on a platform balance to measure the lift force in still air.

A watt meter was used to measure power input and a strobotac to indicate rpm.

DISCUSSION OF RESULTS

The results obtained from the test data and pertinent propeller data of Reference 2 are plotted on graphs 1 to 17 of this report. The check of the physical characteristics of the propeller under test indicates that the data of Reference 2, figure 18, Propeller D of minimum camber, can be applied with negligible error.

Graph 1 is a plot of lift force in pounds on the 1/3-scale channel wing for the three pulley ratios used and with propeller removed at various tunnel speeds. Graph 2 is a plot of the lift data obtained by the three different methods of installation. Inspection of these

DISCUSSION OF RESULTS (cont'd)

curves shows a variation in lift force with the method of mounting. Slightly greater lift was obtained with mounting Method No. 3 than with either 1 or 2. Since the hinge moment method does not include the probable negative lift on the propeller disc., motor, and supporting structure caused by cross flow, higher lift would be expected. The difference in lift between Methods 1 and 3 (both of which measured only channel lift) may be partly due to a small difference in propeller clearance which was not controlled as well in Method No. 1 as in Methods 2 and 3. Interference may have contributed to this difference in lift obtained from the various mounting methods.

The propeller rpm of graph 3 and the power input of graph 5 were obtained simultaneously with the lift data of graph 1.

The electrical power input, which includes the losses in the motor, belt and propeller shaft as well as the power supplied to the propeller, is plotted versus airspeed for each of the pulley ratios on graph 5.

Graph 7 is a plot of the horsepower absorbed by the propeller versus the electrical power input for the three different pulley ratios. The horsepower absorbed at the various airspeeds and propeller rpm was calculated from propeller data of Reference 2.

Graph 8 shows the variations of L/S with T/D^2 at various tunnel speeds for the three pulley ratios. L/S is the total lift in pounds on the model divided by the projected area of the channel wing (29" x 24") 4.96 sq. ft. T/D^2 is the calculated thrust (Reference 2) on the model propeller divided by its diameter squared.

DISCUSSION OF RESULTS (cont'd)

Both thrust coefficient, T_c, and the increment in lift coefficient, ΔC_L, due to the slipstream created by the propeller, are plotted versus tunnel speed on graphs 9 through 12 for the various methods of mounting and at the different angles of attack.

In graphs 13 to 16, derived from graphs 9 to 12, is plotted the variation of ΔC_L with T_c. $T_c = \frac{T}{\rho V^2 D^2}$, and is a measure of the slipstream velocity at the propeller disc. Since it was anticipated that the increment of lift due to propeller operation on the device under test would be a function of slipstream velocity, the parameter T_c was selected as the primary variable for presentation of the basic test results. The test results as given in Figure 15 are in accordance with the variation expected and show a straight line relation between ΔC_L and T_c. It is thus shown that the lift production phenomenon of the present device is of the same nature as that which exists in conventional wing-propeller arrangements. That the present device is somewhat more effective in producing lift than conventional arrangements is probably due to the channeling effect of the duct on the propeller inflow and to effects of the propeller trailing vortices.

The thrust data obtained with the whole model suspended afford a comparison between the calculated and measured thrust coefficient, T_c, of the propeller (graphs 10 and 11). The measured thrust of the propeller was approximately 11 pounds at 16.8 mph, the lowest airspeed obtainable in the tunnel with a model propeller rpm of 3150 rpm. This value agrees closely with the calculated thrust obtained from Reference 2 for the same conditions.

Channel Lnth

DISCUSSION OF RESULTS (cont'd)

The lift force obtained with the entire model mounted on a balance outside of the wind tunnel was 7.5 pounds as compared to an average of about 9 pounds obtained in the tunnel at a tunnel speed of 16.8 mph. This effect is probably due in part to the tunnel guiding the direction of flow, that is from the front and not from all sides as in the open air. Also since the operation of the model motor and propeller created a tunnel velocity of 16.8 mph, it was impossible to obtain static conditions in the tunnel, and the induced flow in the tunnel undoubtedly produced some lift.

This test did not survey the field of variations such as propeller blade angle, blade design, aspect ratio of channel and a wide range of power.

In order to better evaluate the device under test, a comparison has been made with other data available concerning lift increment with power, and the results applied to the Custer airplane.

Reference 3 is a report of tests conducted in the NACA 20-foot wind tunnel on a wing of Clark Y section with 15.5-foot span and 3.16-foot chord. 60 percent of the wing area was swept by the slipstream from two 4-foot diameter propellers. The motors were mounted in tractor positions with the thrust axis zero degrees to the wing chord.

Reference 4 is a report of tests conducted in the NACA full-scale tunnel on a 1/4-scale model of the XB-15, a four-engine bomber. Both pusher and tractor arrangements were tested. 46 percent of the wing area was swept by the slipstream. The airfoil section of this model was an NACA .0018 at the root and .0010 at the tip. The thrust axis was -4-1/2 degrees to the wing chord.

DISCUSSION OF RESULTS (cont'd)

In calculating the data for this comparison, the following method was used for every example. The lift due to power from the referenced tests was attributed to only that area which was swept by the slipstream. The resulting ΔC_L was then applied to an area equal to the projected area of the channels of the Custer airplane. The increment in lift force thus obtained is shown on graph 18. For any given airspeed the thrust coefficient, T_c, was held constant for all examples shown.

The lift without slipstream of the Custer airplane, with an assumed normal wing, was calculated by normal methods at various airspeeds. The wing area used was the projected area of both channels and the outer wing panels. The C_L at 12 degrees angle of attack was assumed to be 80 percent of the $C_{L\ max.}$ for a Gottingen 398 section.

This power-off lift was then added to the lift increment due to power for each of the examples, to obtain the total lift for the Custer airplane, with channels, or with a normal wing and tractor propellers, or with a normal wing and pusher propellers.

All lift data due to power shown on graph 18 include the lift component due to inclination of the thrust. The data used from this test were those obtained with the entire model suspended, since this included the forces on the propeller, motor and supporting structure as is the case in the full-scale airplane.

Graph 18 indicates the take-off speed of the Custer airplane with channels and pusher propellers is 36 mph. This is in comparison to a take-off speed of 51 mph if the channel section were replaced by a normal wing section and no slipstream effect were present. Based on

DISCUSSION OF RESULTS (cont'd)

data of Reference 3, slipstream effect for two tractor propellers reduces the take-off speed of a comparable airplane with normal wing to 42 mph. Slipstream data from Reference 4 applied to an airplane with normal wing results in a take-off speed of 46 mph with tractor propellers and 49 mph with pusher propellers.

In order to evaluate the device under test as a means of producing static lift, the wind-tunnel results were compared with data of a representative helicopter. This comparison shows that the static lift of the device under test is 8.4 pounds per horsepower, while that of the helicopter is 15.2 pounds per horsepower.

CONCLUSIONS

1. Upon the basis of the results of the present tests it is concluded that the increment of lift due to propeller operation on the device under test is caused by the slipstream velocity and is of the same nature as that existing with conventional wing-propeller arrangements.

2. The magnitudes of the lift increments obtained show that the present device is markedly inferior to the helicopter in producing static lift, but is superior to conventional wing-propeller arrangements in producing both static lift and lift when forward velocity exists.

3. The present device does not show sufficient promise of military value to justify further development by the Army Air Forces.

RECOMMENDATIONS

It is recommended that no further consideration of the present device be given until improvements, expected by the inventor, have been verified.

REFERENCES

1. "Lift Forces on Custer Model Scoop with G-398 Airfoil Section," by L. H. Crook.
   Aerodynamical Laboratory Report No. 571, Catholic University, Washington, D. C.

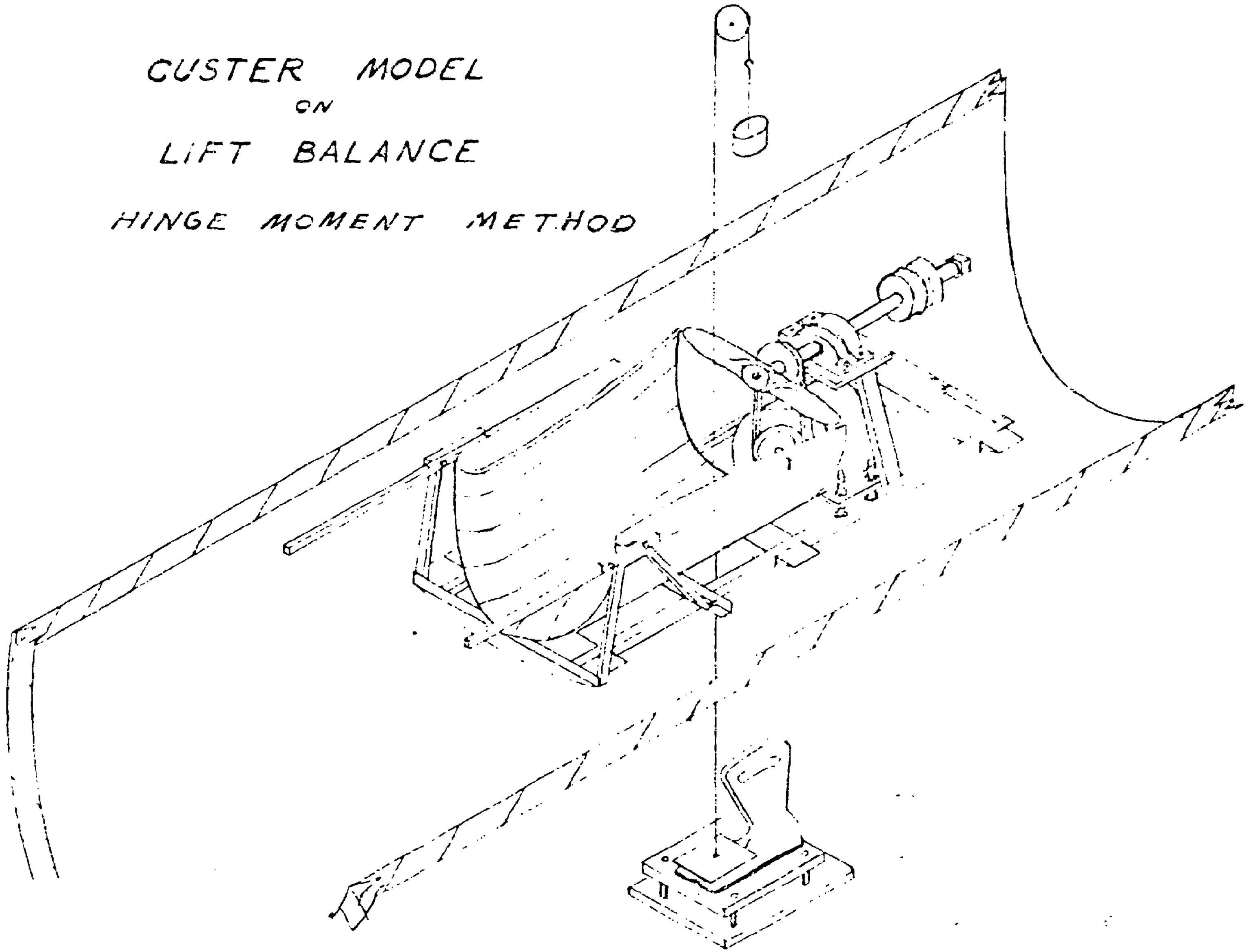
2. "Tests on Thirteen Navy Type Model Propellers" by W. F. Durand
   N.A.C.A. Report No. 237 1926.

3. "The Effect of Propellers on the Lift of a Wing," by John L. Crigler
   N.A.C.A. Preliminary Data, 31 January 1939.

4. "Full-Scale Wind-Tunnel Tests on the XBLR-1 with Motors Enclosed in the Wings and Extension Shafts to Propellers in Tractor and Pusher Position," by Abe Silverstein and H. A. Wilson
   N.A.C.A. Memorandum Report, 27 October 1937.

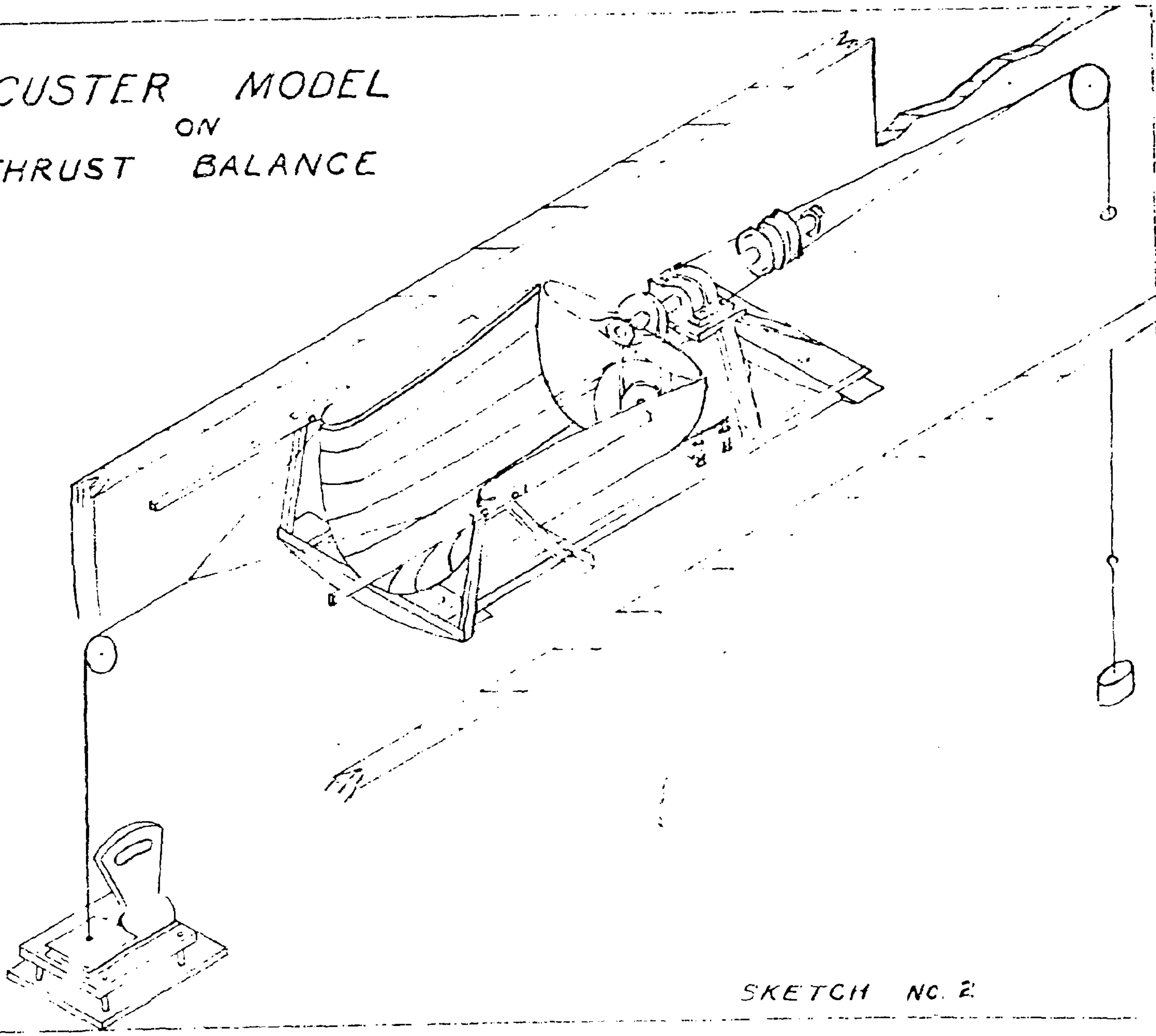
CUSTER MODEL
ON
LIFT BALANCE

HINGE MOMENT METHOD



SKETCH NO. 1

CUSTER MODEL
ON
THRUST BALANCE



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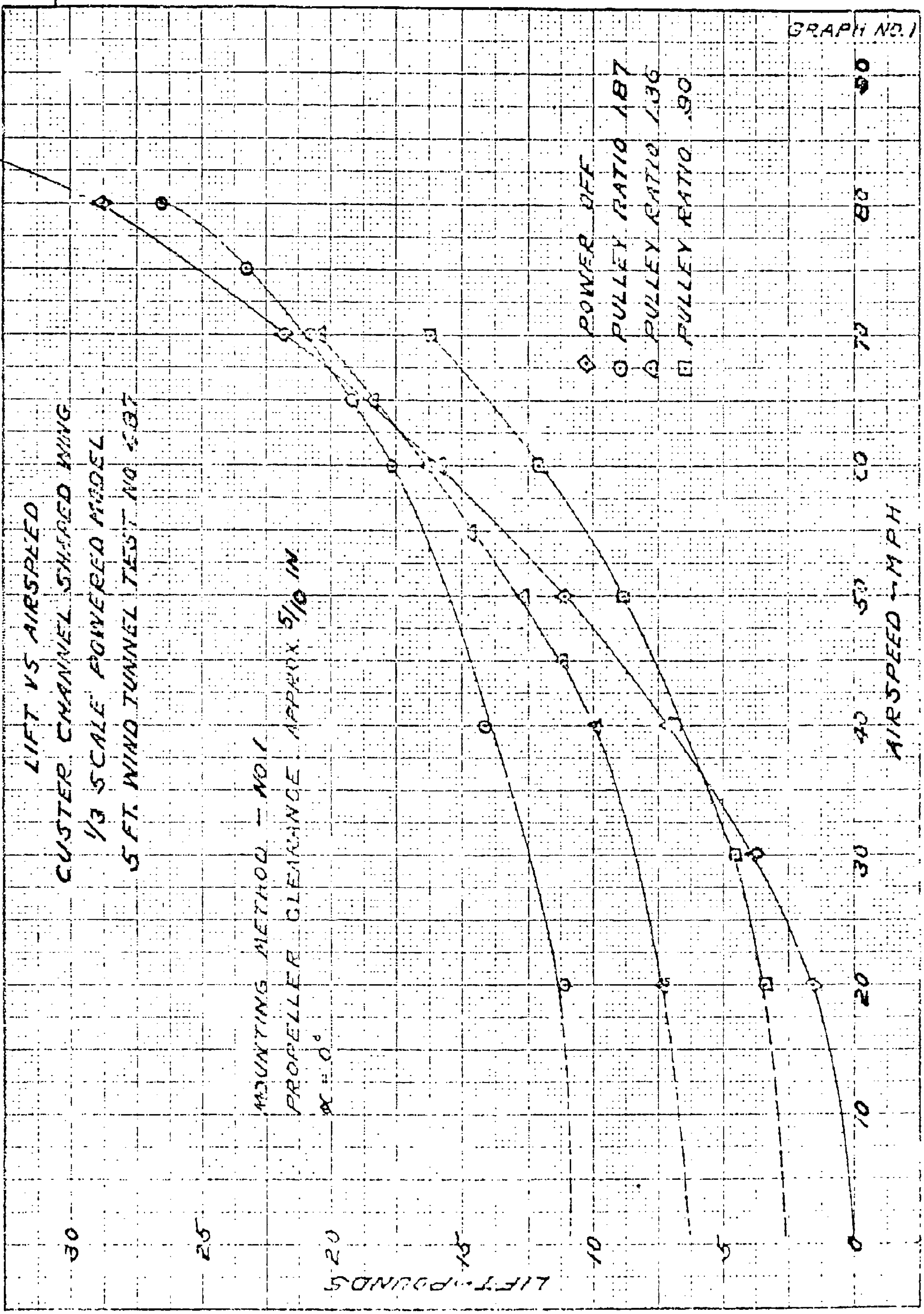
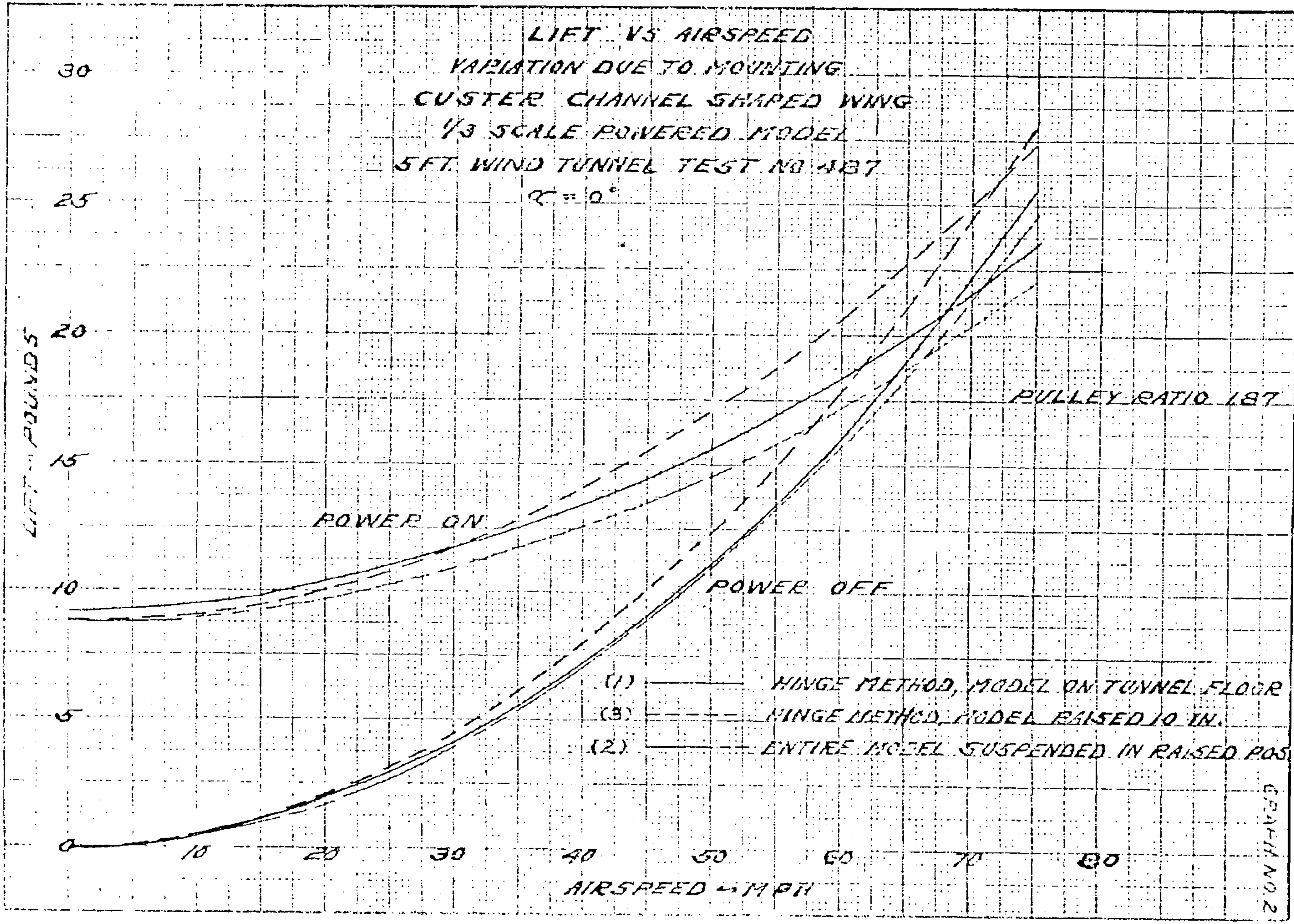
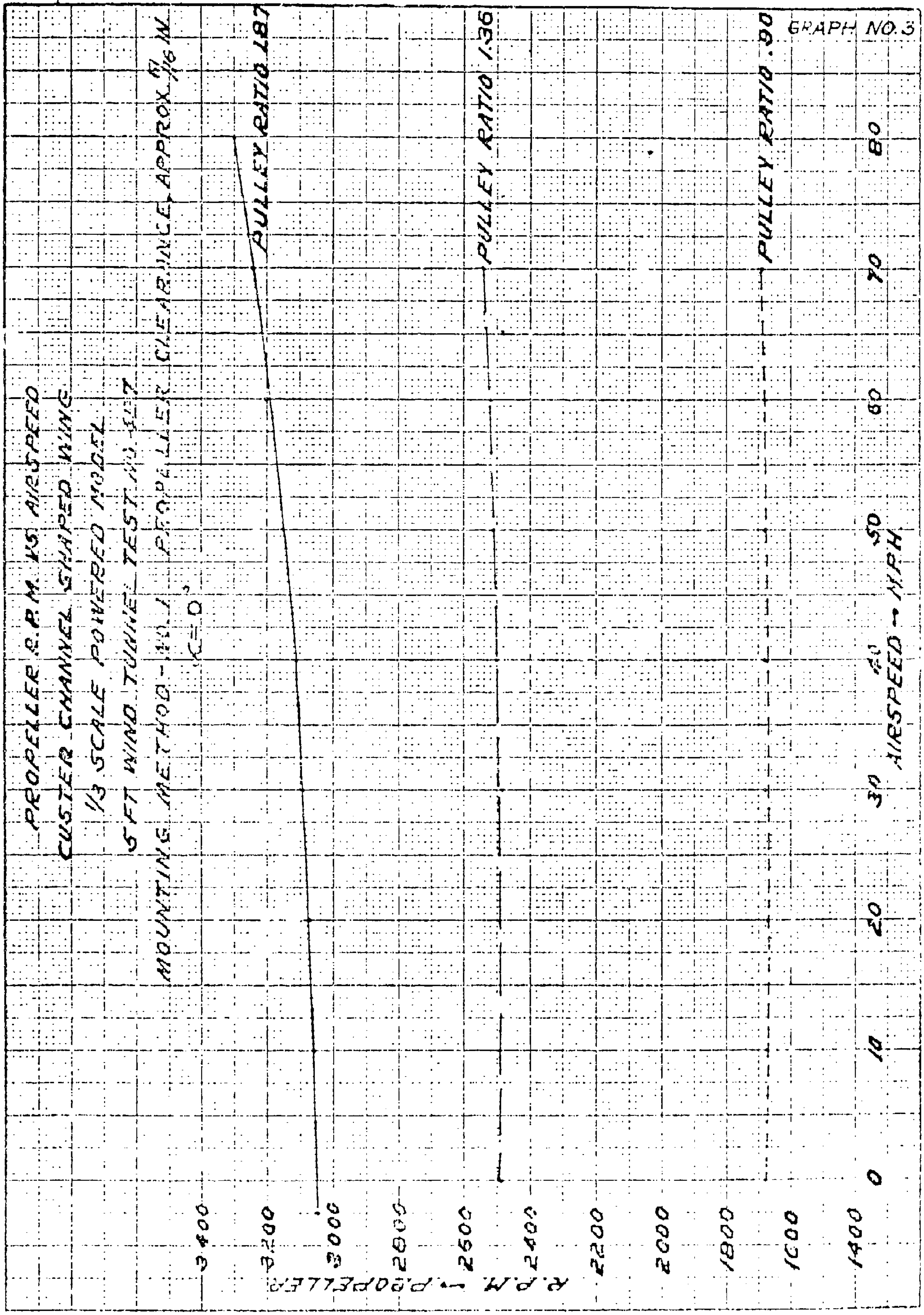
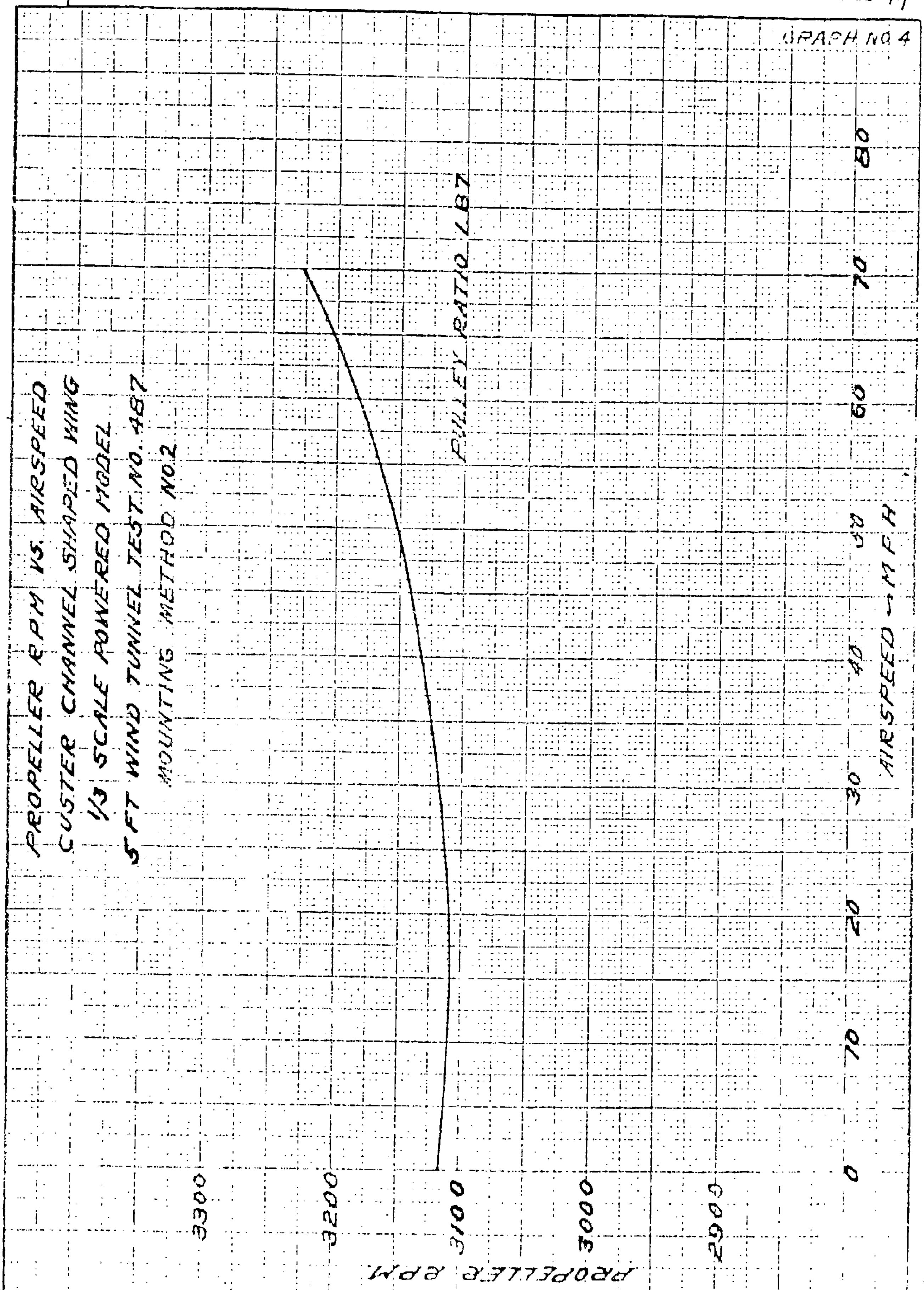
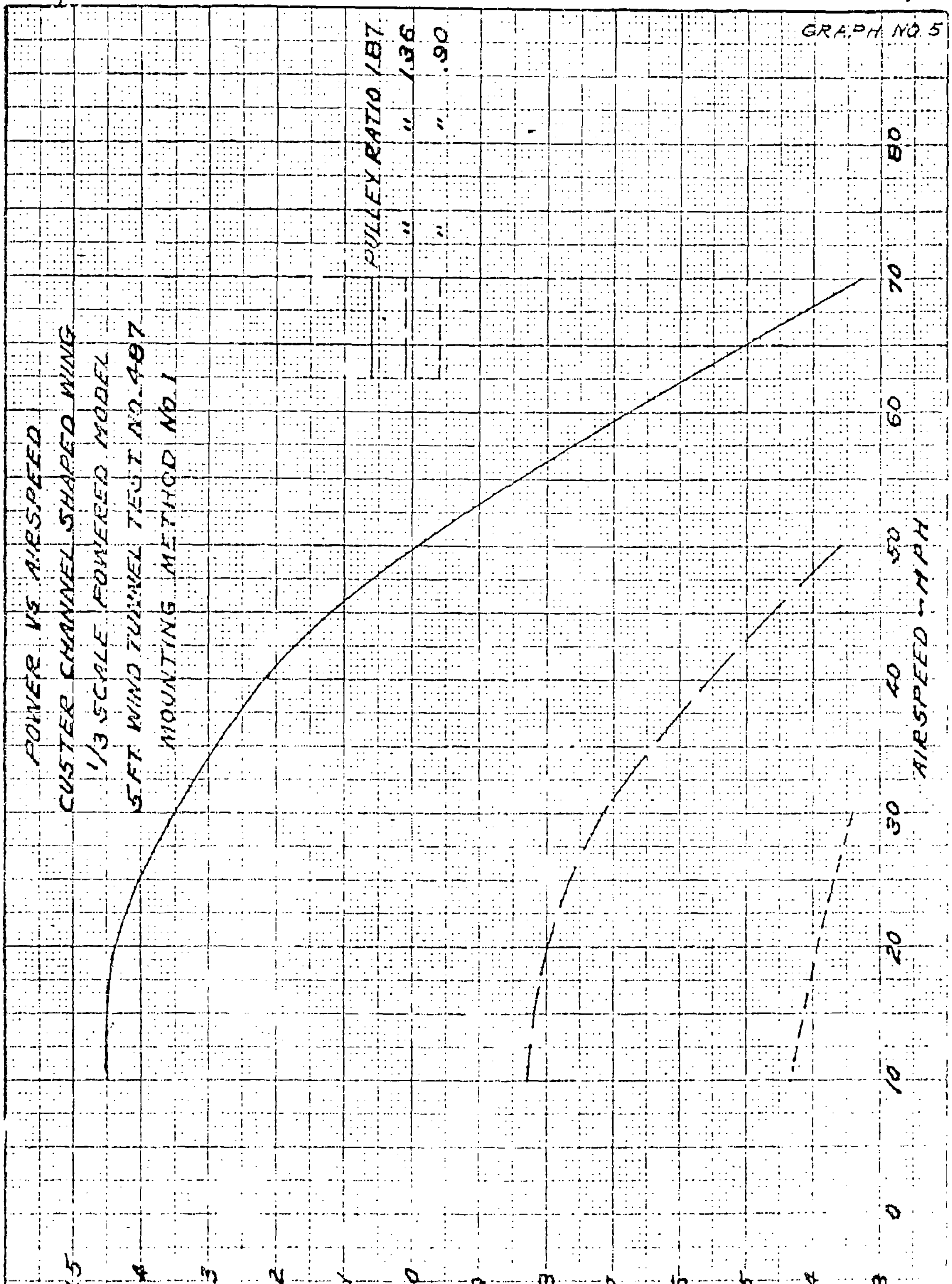

GRAPH NO. 1
LIFT VS AIRSPEED
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT. WIND TUNNEL TEST NO
MOUNTING METHOD — NO 1
PROPELLER CLEARANCE APPROX. 5/10 IN.
α = 0°
POWER OFF
PULLEY RATIO 1.87
PULLEY RATIO 1.36
PULLEY RATIO .90
LIFT — POUNDS
AIRSPEED — MPH
0
5
10
15
20
25
30
10
20
30
40
50
60
70
80
90


GRAPH NO. 2
LIFT VS AIRSPEED
VARIATION DUE TO MOUNTING
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT. WIND TUNNEL TEST NO 487
α = 0°
PULLEY RATIO 1.87
POWER ON
POWER OFF
(1) HINGE METHOD, MODEL ON TUNNEL FLOOR
(3) HINGE METHOD, MODEL RAISED 10 IN.
(2) ENTIRE MODEL SUSPENDED IN RAISED POS
LIFT ~ POUNDS
AIRSPEED ~ MPH
0
5
10
15
20
25
30
10
20
30
40
50
60
70
80

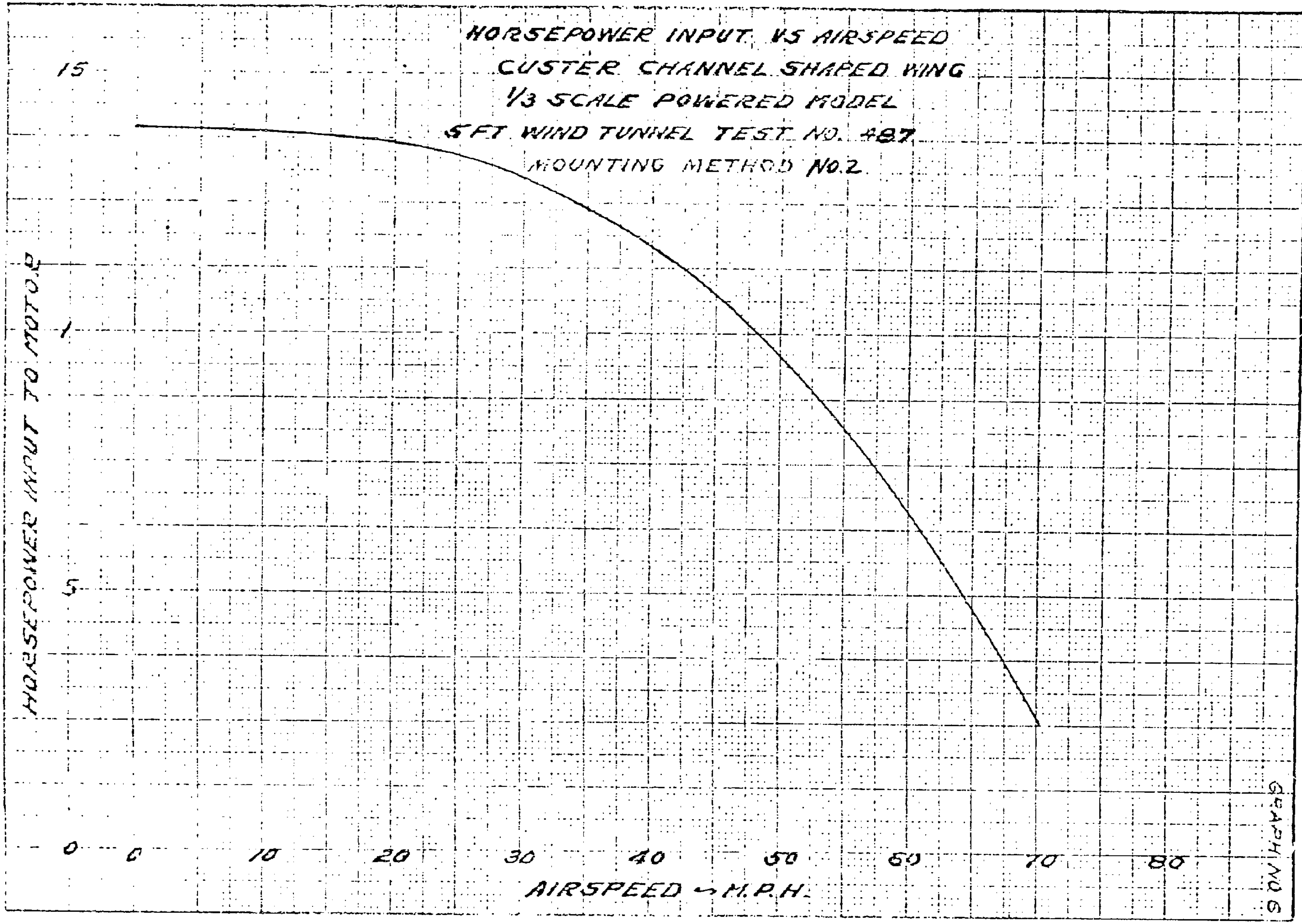
SERIAL No.

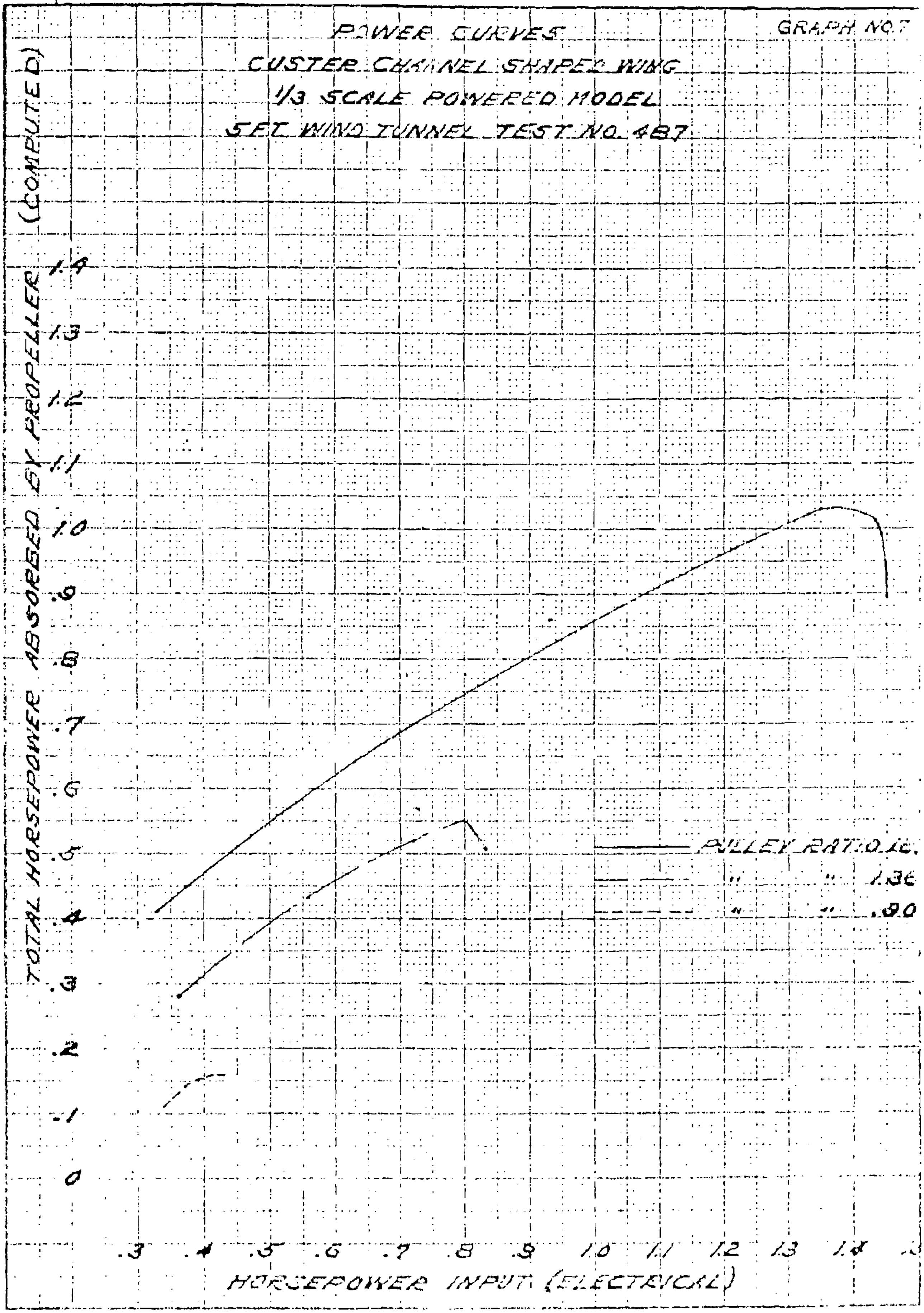

GRAPH NO. 3
PROPELLER R.P.M. VS AIRSPEED
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT WIND TUNNEL TEST
MOUNTING METHOD - NO 1 PROPELLER CLEARANCE APPROX 1/16 IN
PULLEY RATIO 1.87
PULLEY RATIO 1.36
PULLEY RATIO .90
R.P.M. - PROPELLER
AIRSPEED - MPH
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
0
10
20
30
40
50
60
70
80


GRAPH NO. 4
PROPELLER RPM VS. AIRSPEED
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT WIND TUNNEL TEST NO. 487
MOUNTING METHOD NO.2
PULLEY RATIO 1.87
0
10
20
30
40
50
60
70
80
AIRSPEED - MPH
3300
3200
3100
3000
2900
PROPELLER RPM

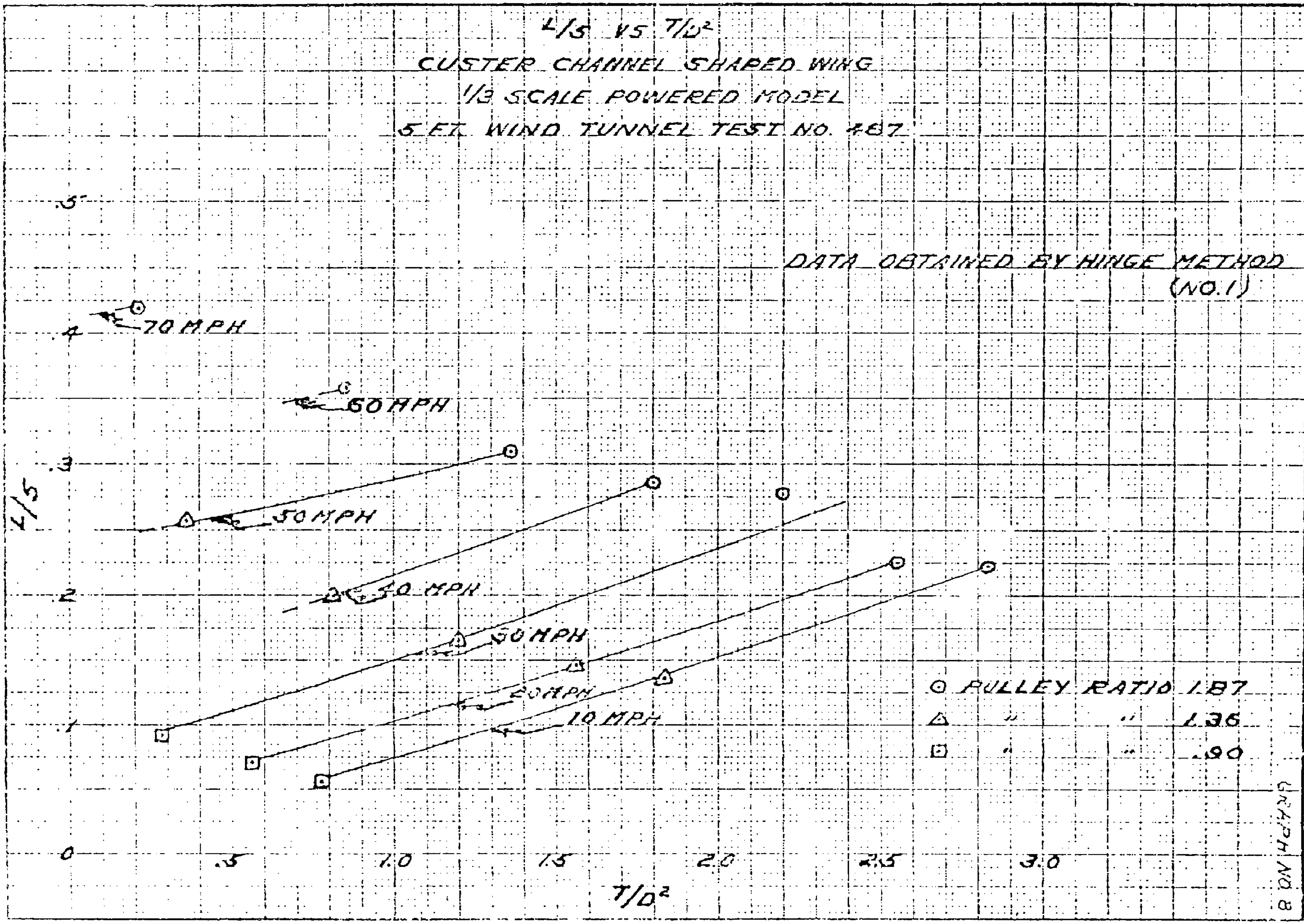

GRAPH NO. 5
POWER VS AIRSPEED
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT WIND TUNNEL TEST NO. 487
MOUNTING METHOD NO. 1
PULLEY RATIO 1.87
" " 1.36
" " .90
0
10
20
30
40
50
60
70
80
AIRSPEED - MPH
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
HORSEPOWER INPUT (ELECTRICAL)

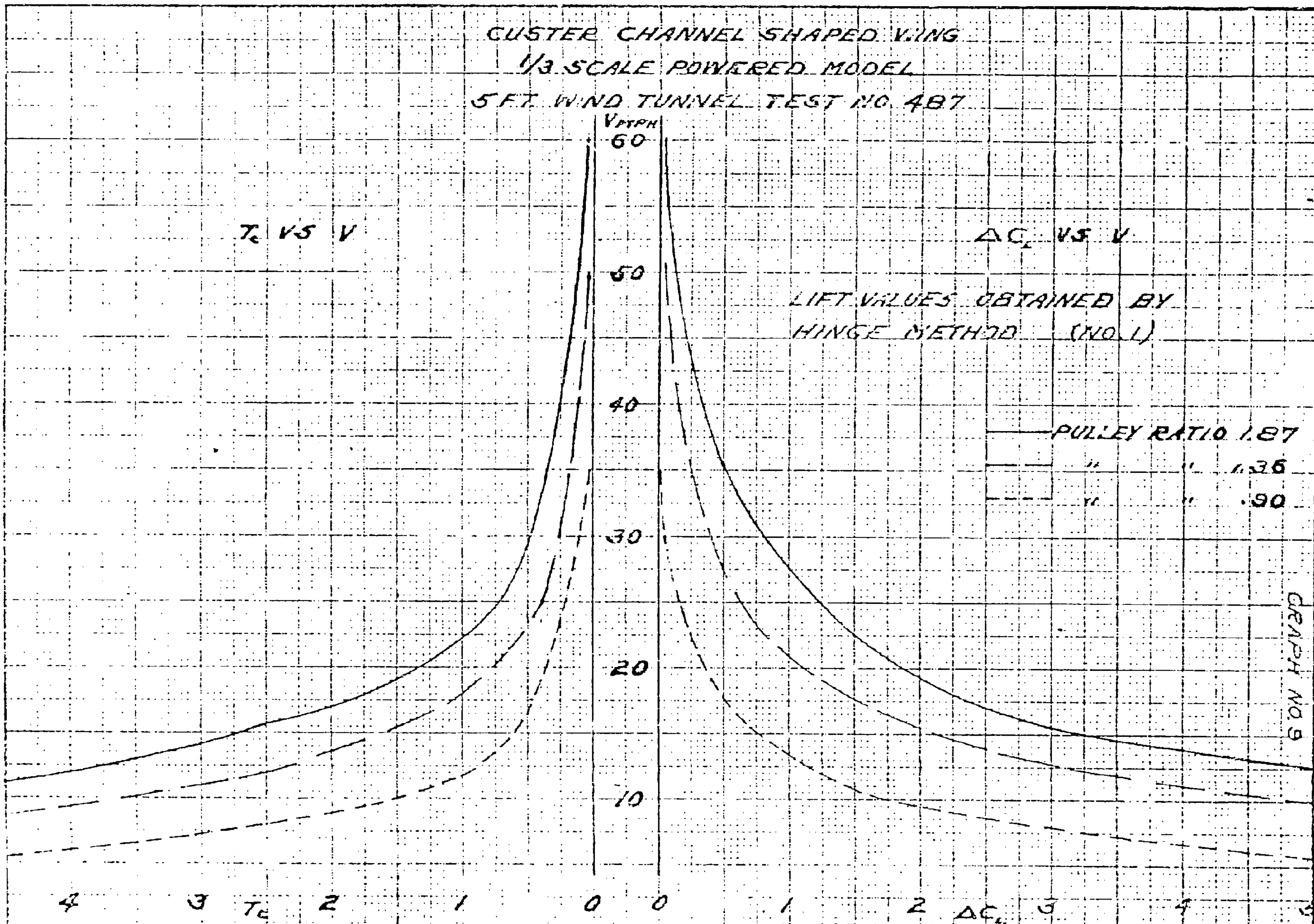
GRAPH NO 6

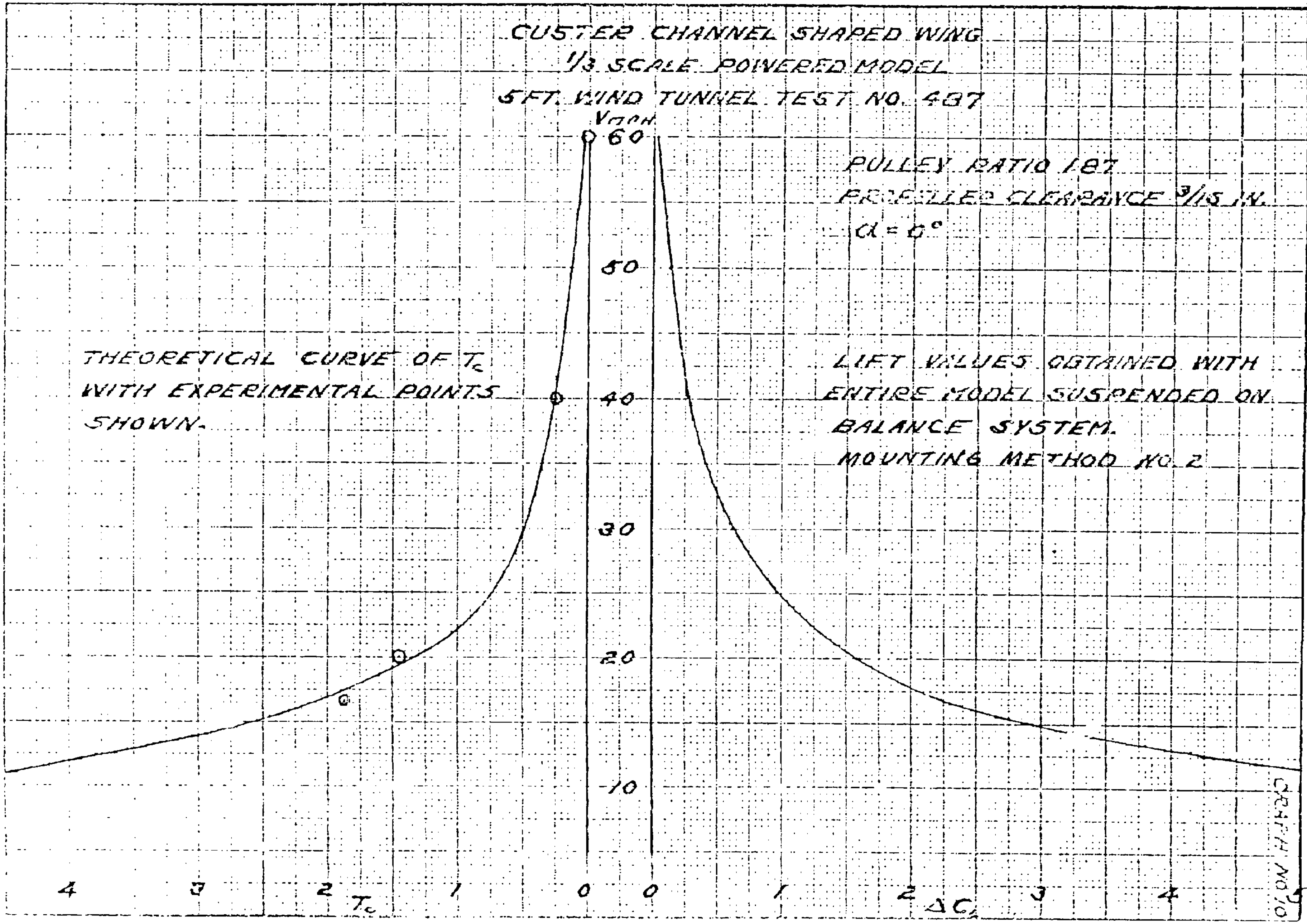

HORSEPOWER INPUT VS AIRSPEED
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT WIND TUNNEL TEST NO. 487
MOUNTING METHOD No.2
15
5
0
0
10
20
30
40
50
60
70
80
AIRSPEED ~ M.P.H.
HORSEPOWER INPUT TO MOTOR

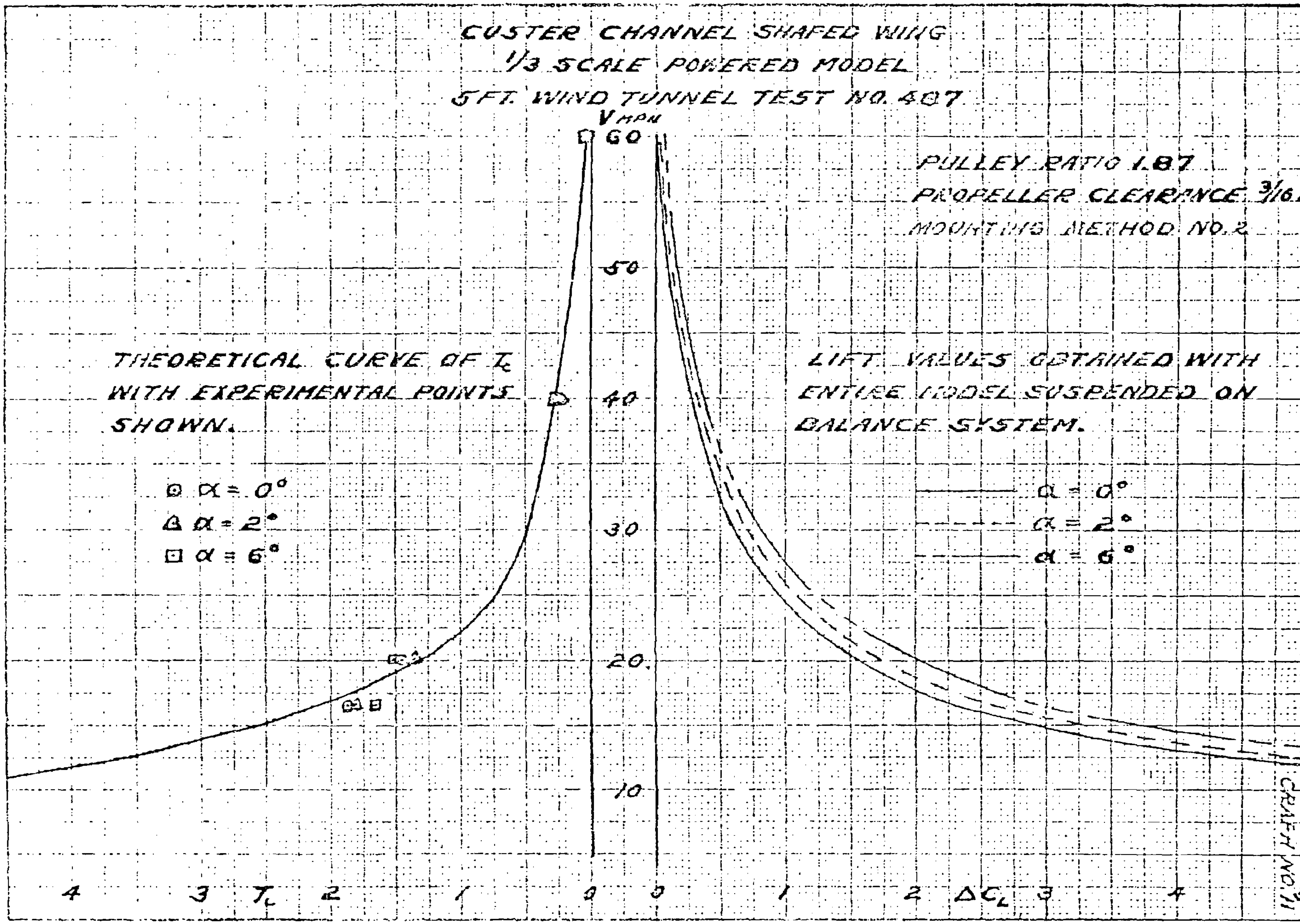

POWER CURVES
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
SET WIND TUNNEL TEST NO. 487
GRAPH NO. 7
TOTAL HORSEPOWER ABSORBED BY PROPELLER (COMPUTED)
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
PULLEY RATIO 1.0
" " 1.36
" " .90
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
HORSEPOWER INPUT (ELECTRICAL)

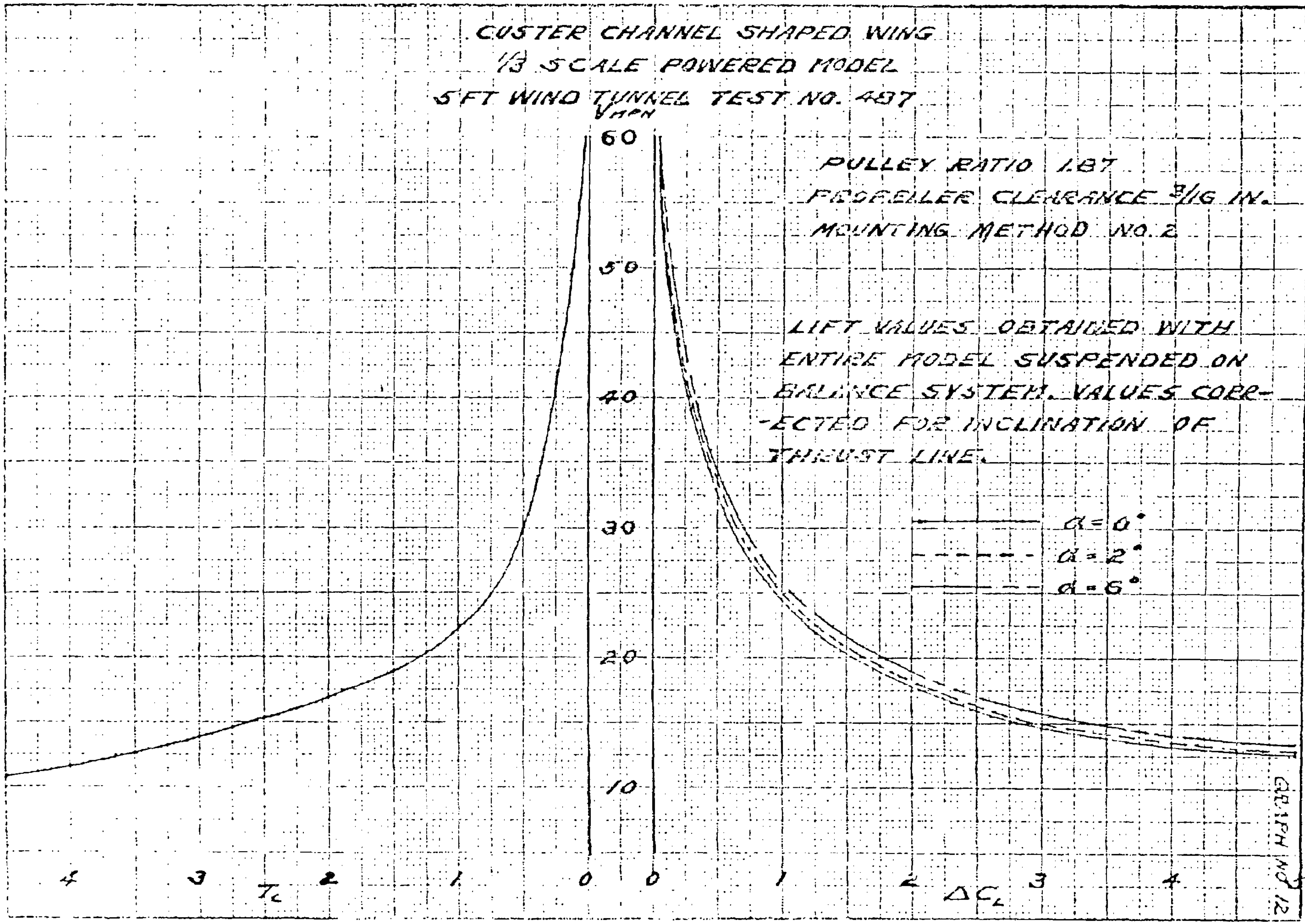
GRAPH NO. 8

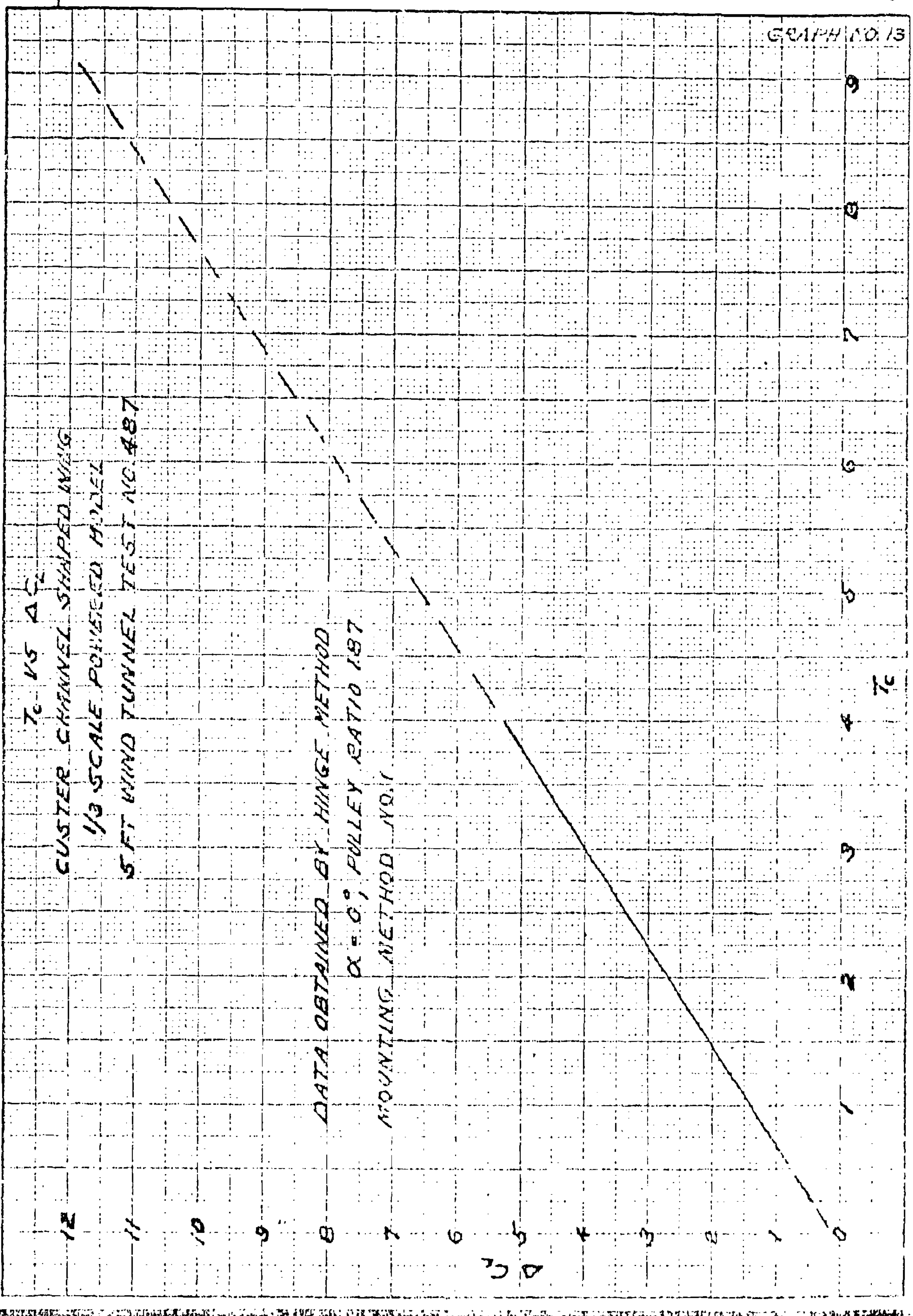

L/S VS T/D²
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT. WIND TUNNEL TEST NO. 487
DATA OBTAINED BY HINGE METHOD
(NO. 1)
70 MPH
60 MPH
50 MPH
40 MPH
30 MPH
20 MPH
10 MPH
⊙ PULLEY RATIO 1.87
△ " " 1.36
⊡ " " .90
L/S
T/D²
0
.1
.2
.3
.4
.5
.5
1.0
1.5
2.0
2.5
3.0

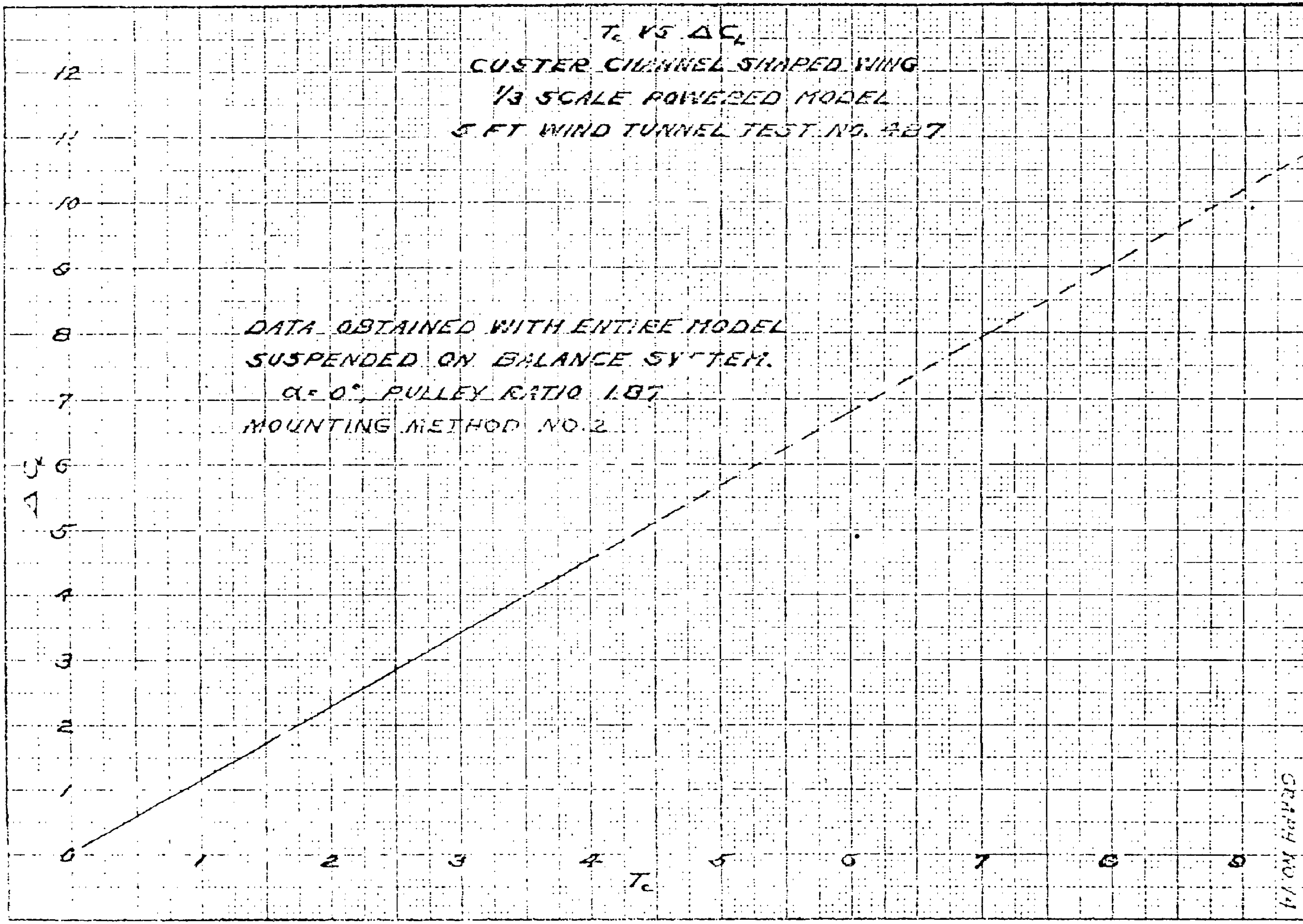

CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT. WIND TUNNEL TEST NO. 487
GRAPH NO. 9
T_c VS V
ΔC_L VS V
LIFT VALUES OBTAINED BY
HINGE METHOD (NO. 1)
PULLEY RATIO 1.87
" " 1.36
" " .90
V_{MPH}
60
50
40
30
20
10
4
3
T_c
2
1
0
0
1
2
ΔC_L
3
4
5

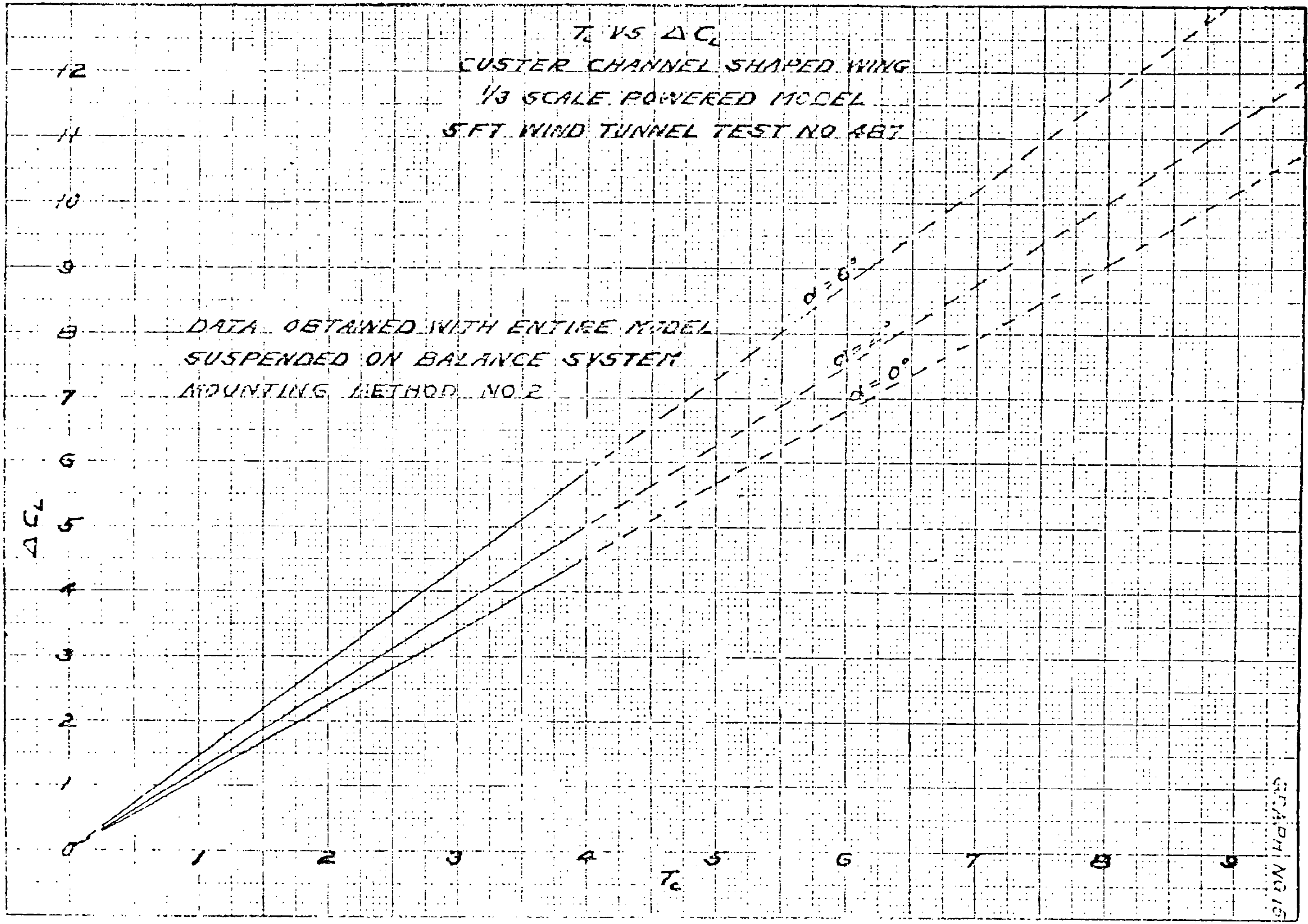

GRAPH NO 10
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5FT. WIND TUNNEL TEST NO. 487
PULLEY RATIO 1.87
PROPELLER CLEARANCE 3/16 IN.
α = 0°
THEORETICAL CURVE OF T_c
WITH EXPERIMENTAL POINTS
SHOWN.
LIFT VALUES OBTAINED WITH
ENTIRE MODEL SUSPENDED ON
BALANCE SYSTEM.
MOUNTING METHOD NO. 2
V_{mph}
60
50
40
30
20
10
4
3
2
1
0
0
1
2
3
4
T_c
ΔC_L

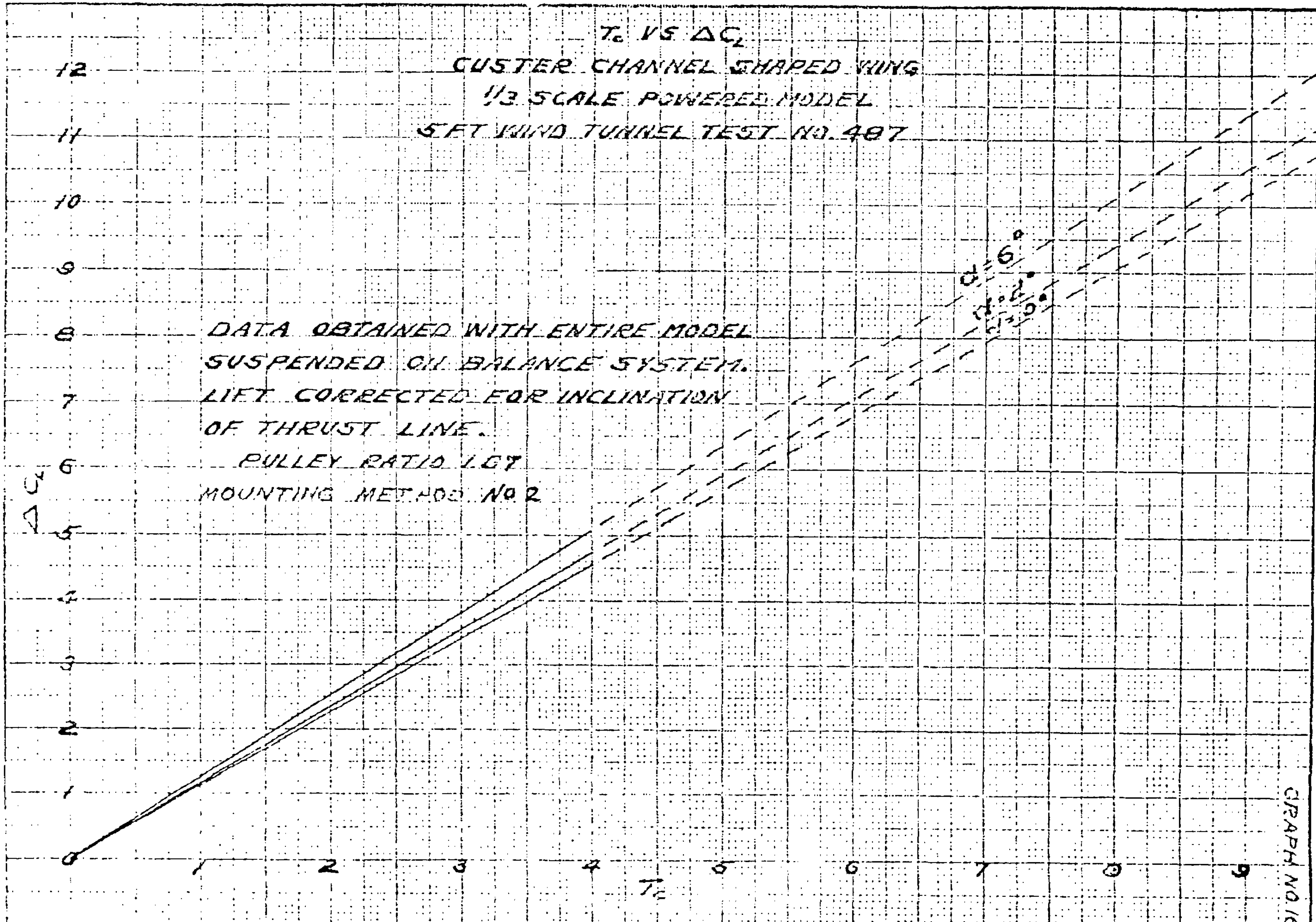

CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5FT. WIND TUNNEL TEST NO. 407
PULLEY RATIO 1.87
PROPELLER CLEARANCE 3/16 IN.
MOUNTING METHOD NO. 2
THEORETICAL CURVE OF T_c
WITH EXPERIMENTAL POINTS
SHOWN.
⊙ $\alpha = 0°$
Δ $\alpha = 2°$
⊡ $\alpha = 6°$
LIFT VALUES OBTAINED WITH
ENTIRE MODEL SUSPENDED ON
BALANCE SYSTEM.
$\alpha = 0°$
$\alpha = 2°$
$\alpha = 6°$
V_{MPH}
60
50
40
30
20.
10
4
3
T_c
2
1
0
0
1
2
ΔC_L
3
4
5
GRAPH NO. 11

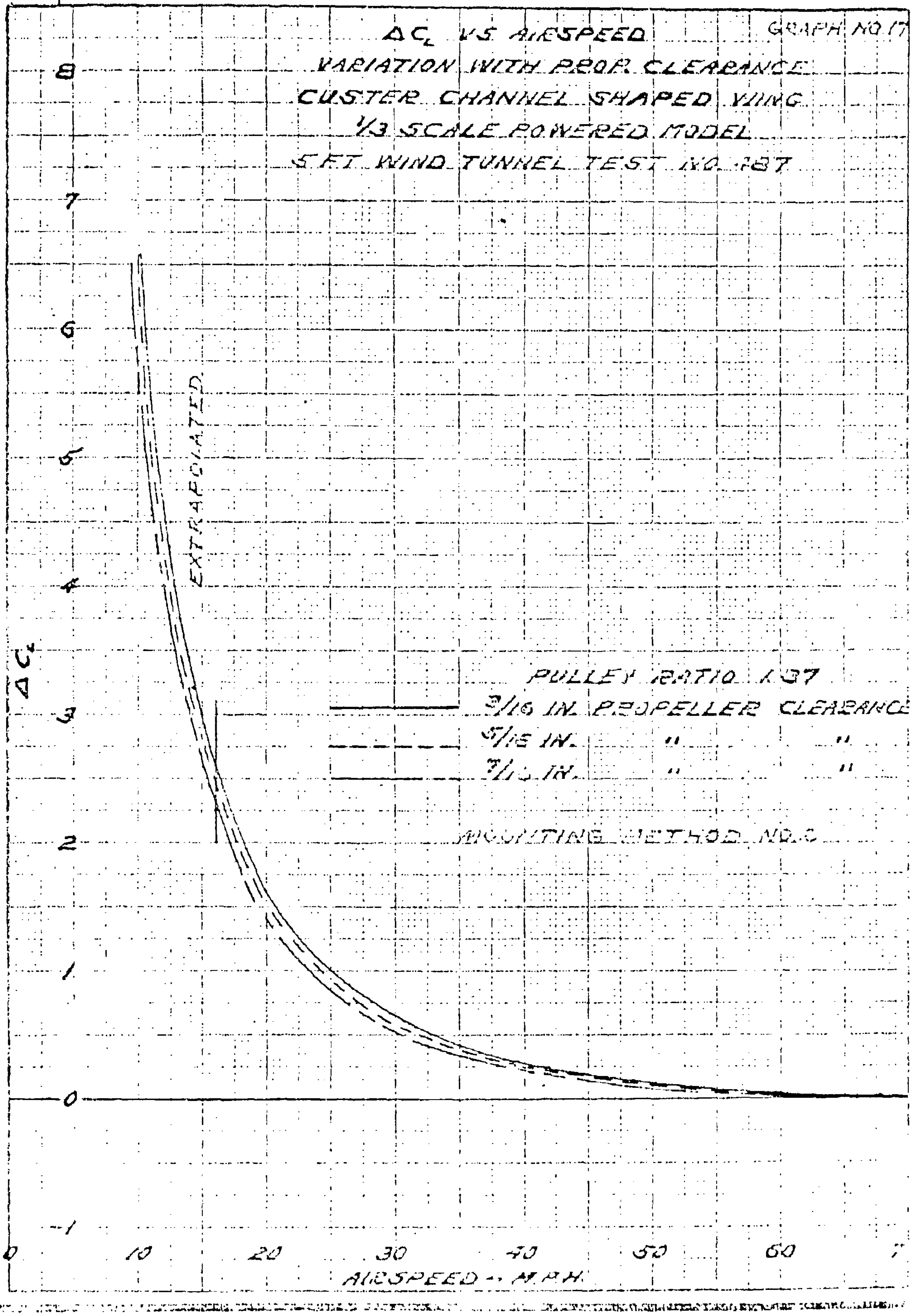

GRAPH NO. 12
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT WIND TUNNEL TEST NO. 487
V_{MPH}
60
50
40
30
20
10
PULLEY RATIO 1.87
PROPELLER CLEARANCE 3/16 IN.
MOUNTING METHOD NO. 2
LIFT VALUES OBTAINED WITH ENTIRE MODEL SUSPENDED ON BALANCE SYSTEM. VALUES CORR-ECTED FOR INCLINATION OF THRUST LINE.
$\alpha = 0°$
$\alpha = 2°$
$\alpha = 6°$
4 3 2 1 0
T_c
0 1 2 3 4
ΔC_L

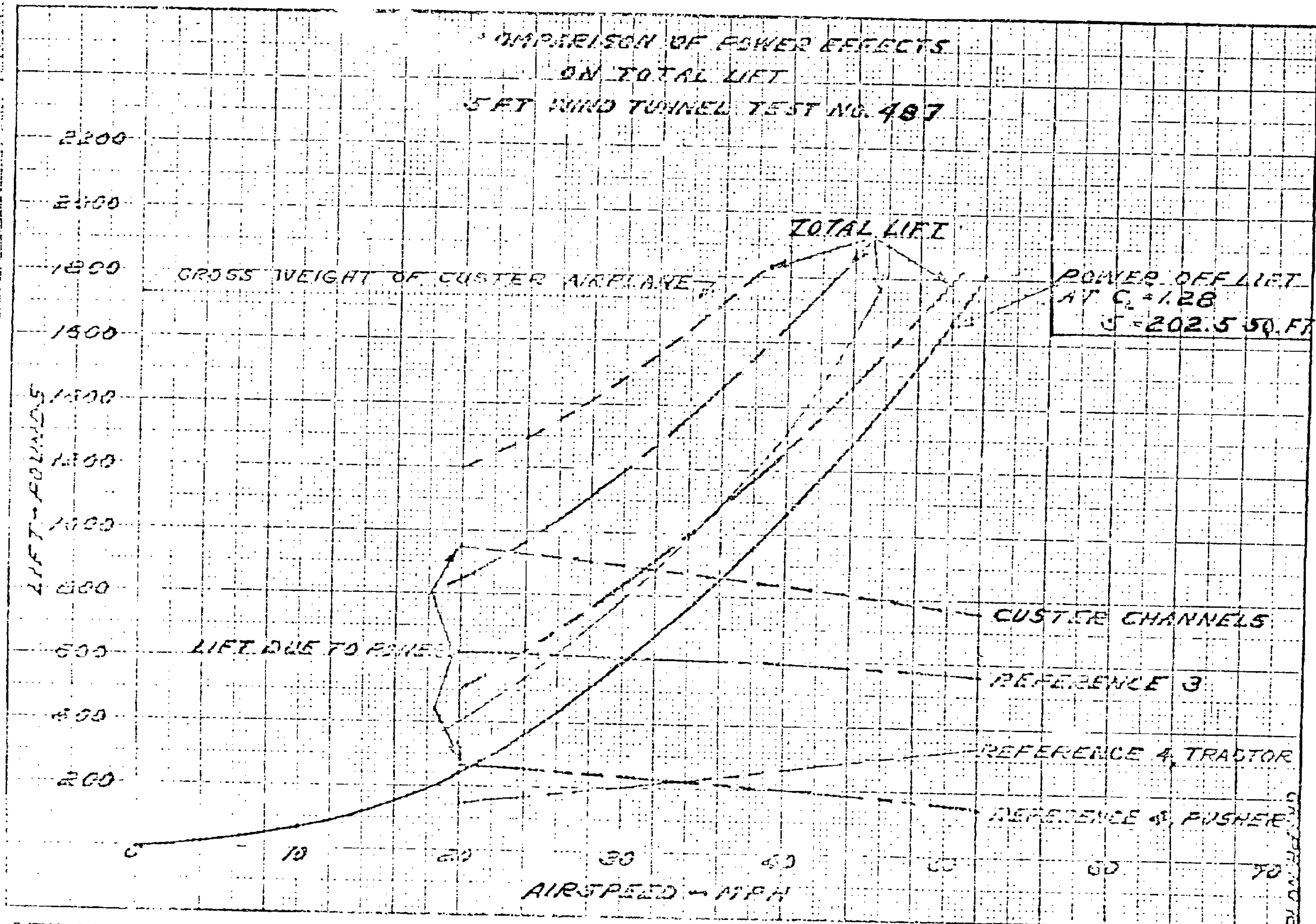

GRAPH NO. 13
T_c VS ΔC_L
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT WIND TUNNEL TEST NO. 487
DATA OBTAINED BY HINGE METHOD
$\alpha = 0°$, PULLEY RATIO 1.87
MOUNTING METHOD NO. 1
T_c
ΔC_L
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9 10 11 12


T_c VS ΔC_L
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT. WIND TUNNEL TEST NO. 487
DATA OBTAINED WITH ENTIRE MODEL
SUSPENDED ON BALANCE SYSTEM.
$\alpha = 0°$, PULLEY RATIO 1.87
MOUNTING METHOD NO. 2
GRAPH NO. 14
ΔC_L
T_c
0
1
2
3
4
5
6
7
8
9
10
11
12


GRAPH NO 15
T_c VS ΔC_L
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT WIND TUNNEL TEST NO 487
DATA OBTAINED WITH ENTIRE MODEL
SUSPENDED ON BALANCE SYSTEM
MOUNTING METHOD NO 2
$\alpha = 6°$
$\alpha = 0°$
ΔC_L
T_c
0
1
2
3
4
5
6
7
8
9
10
11
12

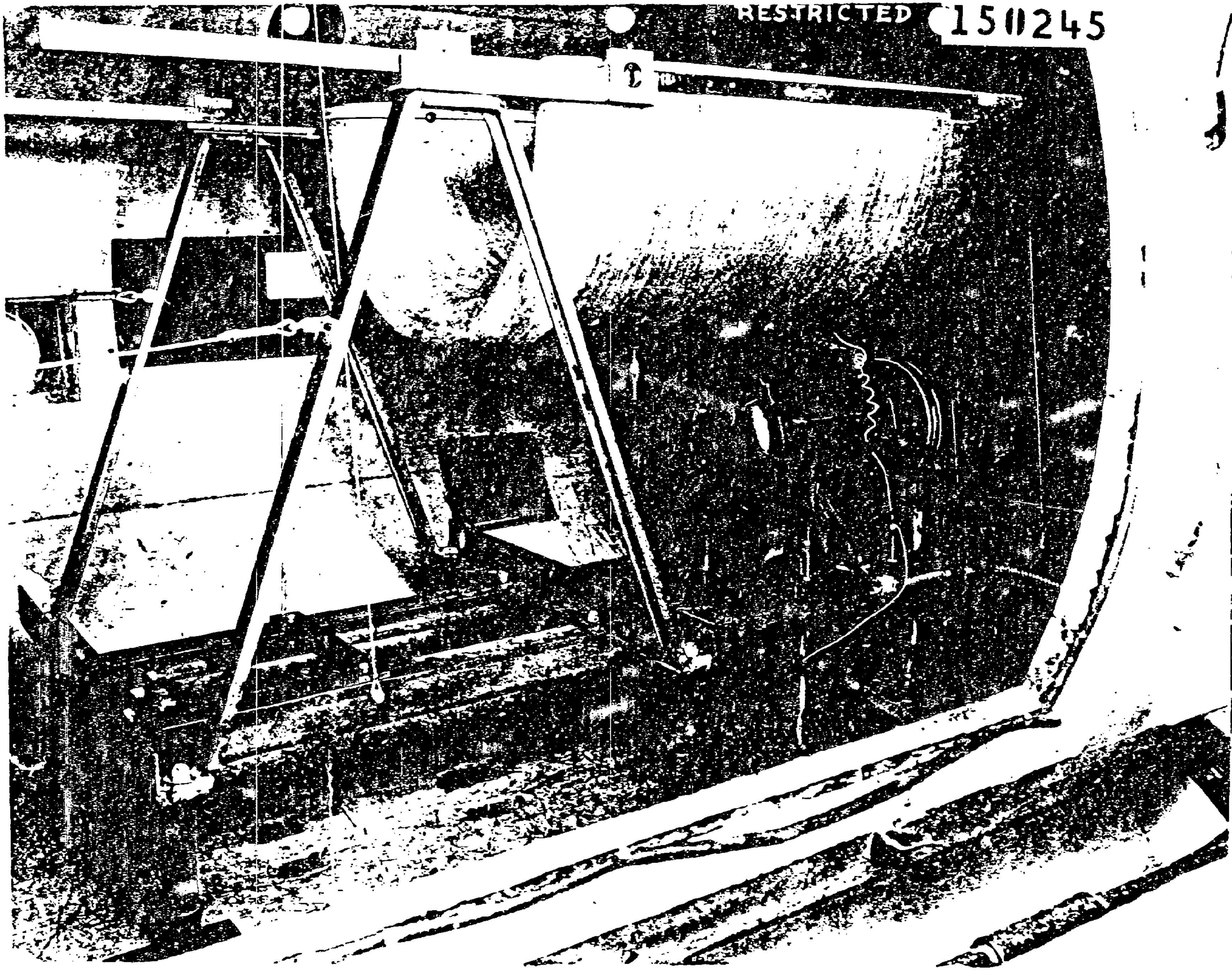

GRAPH NO.16
T_c VS ΔC_L
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT WIND TUNNEL TEST NO. 487
DATA OBTAINED WITH ENTIRE MODEL
SUSPENDED ON BALANCE SYSTEM.
LIFT CORRECTED FOR INCLINATION
OF THRUST LINE.
PULLEY RATIO 1.67
MOUNTING METHOD No 2
$\delta = 6°$
$\delta = 2°$
$\delta = 0°$
ΔC_L
0
1
2
3
4
5
6
7
8
9
10
11
12
T_c


GRAPH NO. 17
ΔC_L VS AIRSPEED
VARIATION WITH PROP. CLEARANCE
CUSTER CHANNEL SHAPED WING
1/3 SCALE POWERED MODEL
5 FT. WIND TUNNEL TEST NO. 187
EXTRAPOLATED
PULLEY RATIO 1.37
3/16 IN. PROPELLER CLEARANCE
5/16 IN. " "
7/16 IN. " "
MOUNTING METHOD NO. 2
ΔC_L
8
7
6
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70
AIRSPEED – M.P.H.


COMPARISON OF POWER EFFECTS
ON TOTAL LIFT
5 FT WIND TUNNEL TEST NO. 487
TOTAL LIFT
GROSS WEIGHT OF CUSTER AIRPLANE
POWER OFF LIFT
AT C_L=1.28
S=202.5 SQ.FT.
CUSTER CHANNELS
LIFT DUE TO POWER
REFERENCE 3
REFERENCE 4, TRACTOR
REFERENCE 4, PUSHER
LIFT - POUNDS
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
10
20
30
40
50
60
70
AIRSPEED - MPH

LIST OF PHOTOGRAPHS

No.	Title
150245	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel with Entire Model Suspended, 3/4 Front View.
150246	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel with Entire Model Suspended, 3/4 Front Close-Up.
150247	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel with Entire Model Suspended, Front View.
150248	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel with Entire Model Suspended, Rear View.
150249	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel with Entire Model Suspended, 3/4 Rear Close-Up.
150250	Counter Weights used to suspend Custer Airplane Model in 5-Ft. Wind Tunnel.
148881	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel for Measuring Thrust, 3/4 Front View.
148882	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel for Measuring Thrust, Front View.
148883	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel for Measuring Thrust, Rear View.
148884	Custer Channel Wing Model, Installation in 5-Ft. Wind Tunnel for Measuring Lift of Wing, Front View.
148885	Left Side, Lift Moment Scale with Safety Stop to Prevent Wing and Propeller from contacting. Right Side, Counter Weight used to Maintain Tension in Scale System when Measuring Lift of Wing.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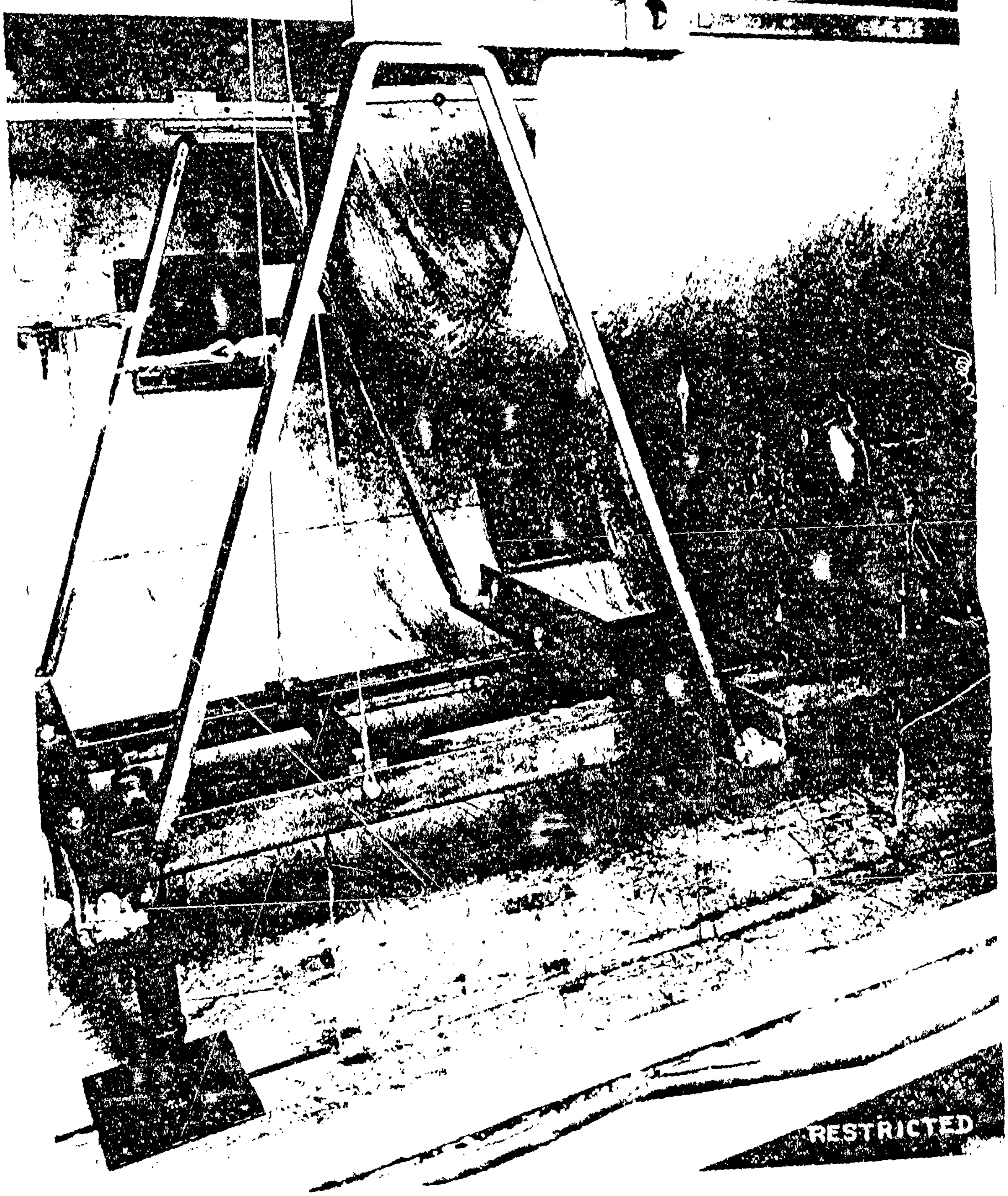
150245

150246



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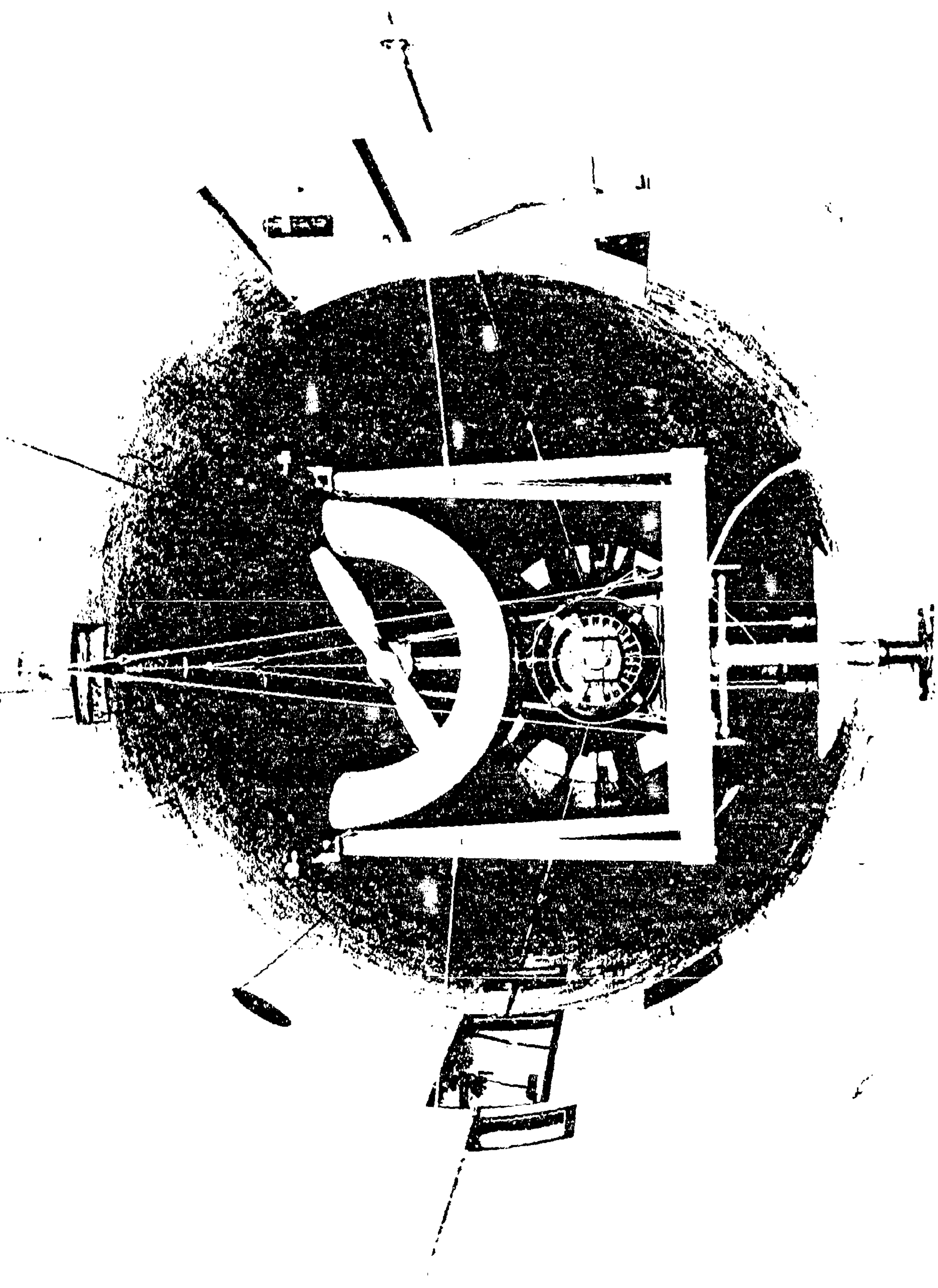

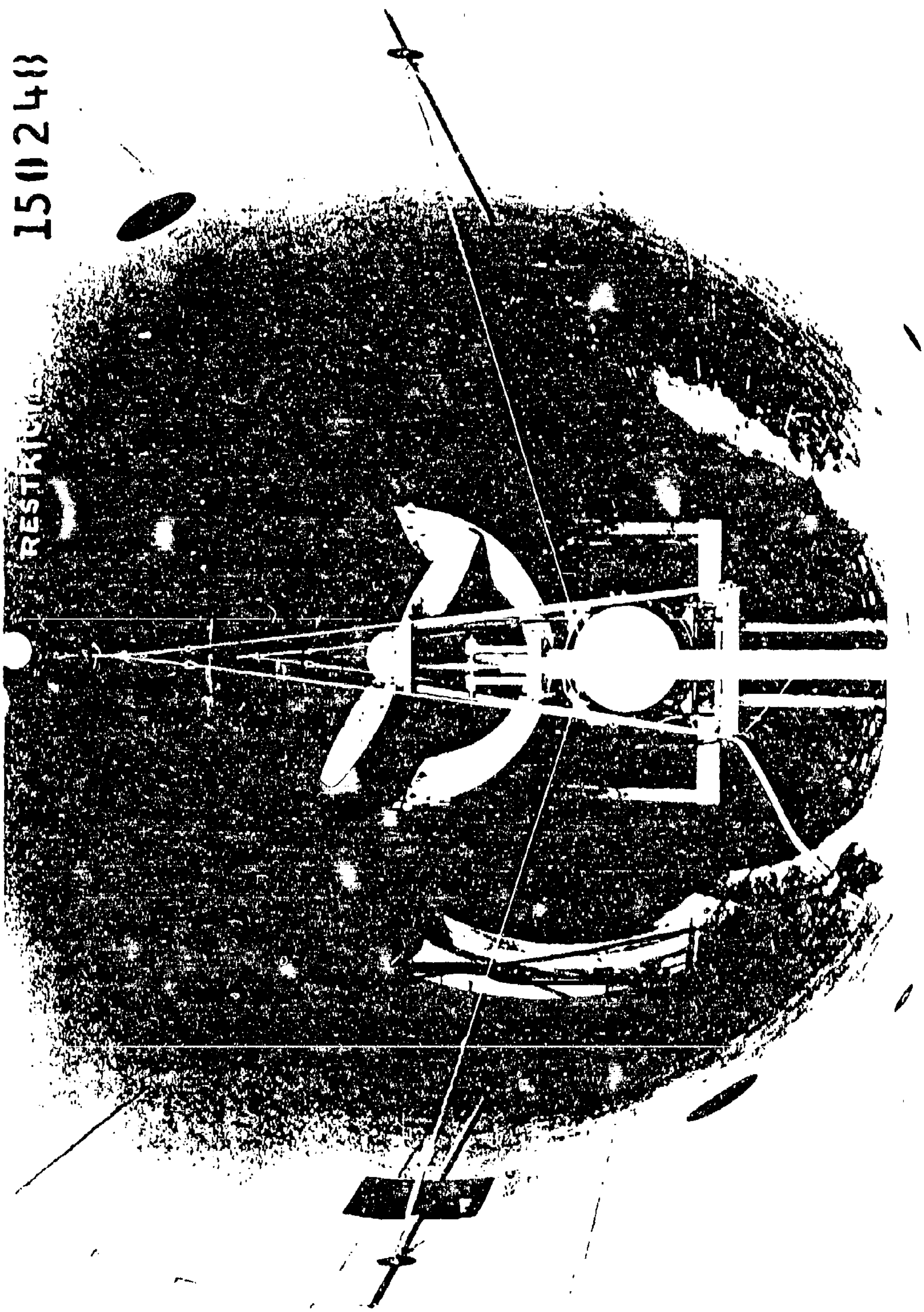

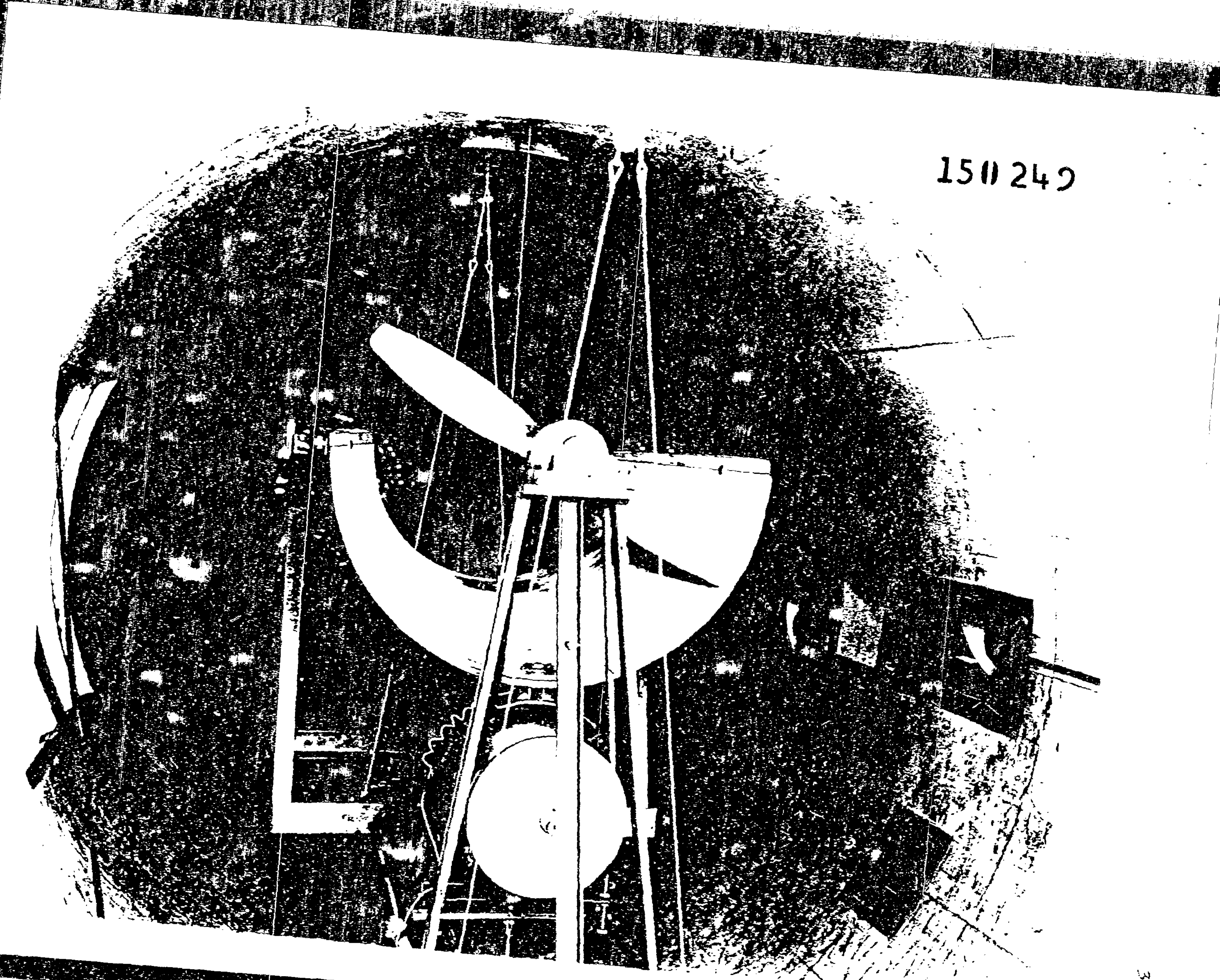
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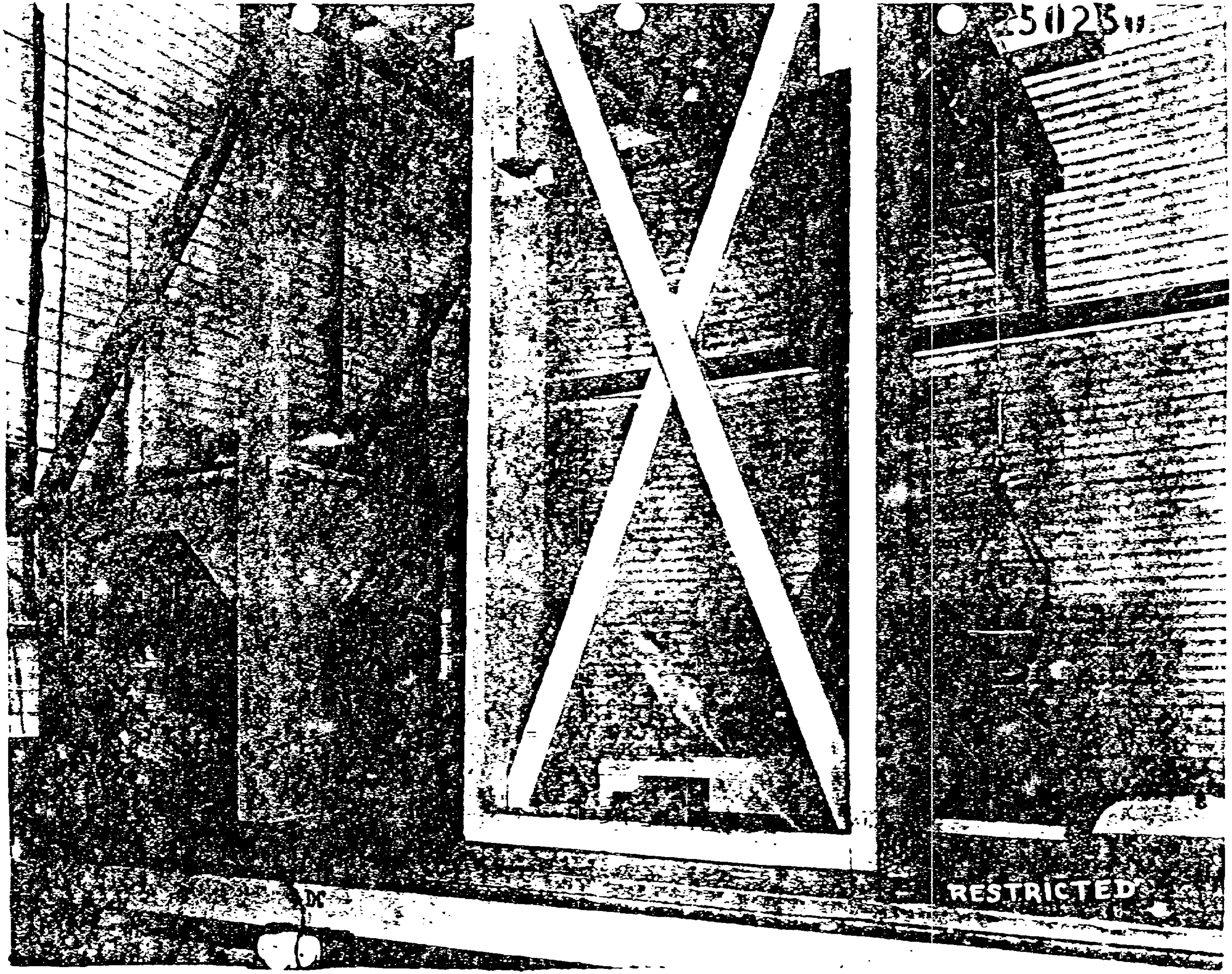
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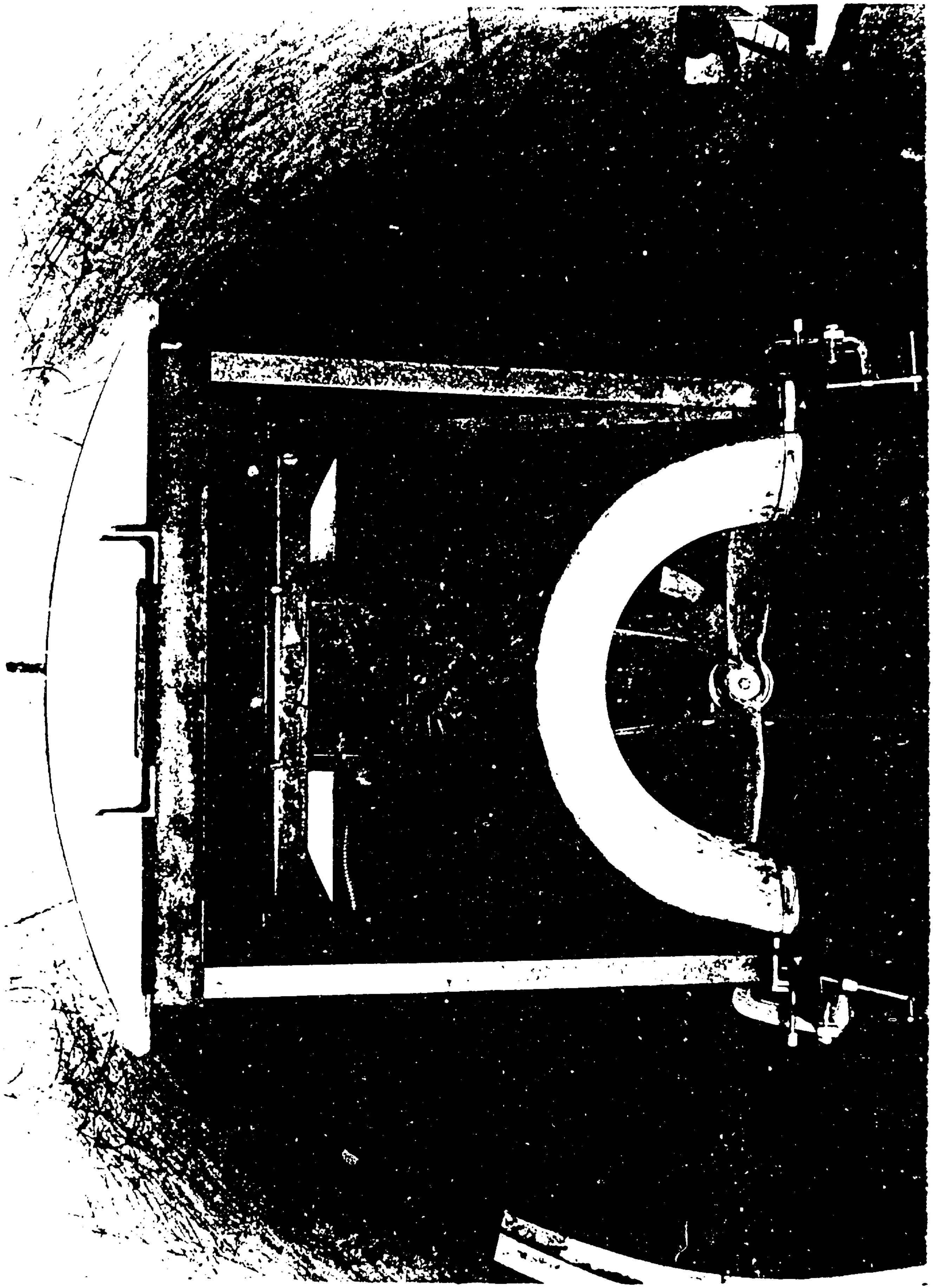

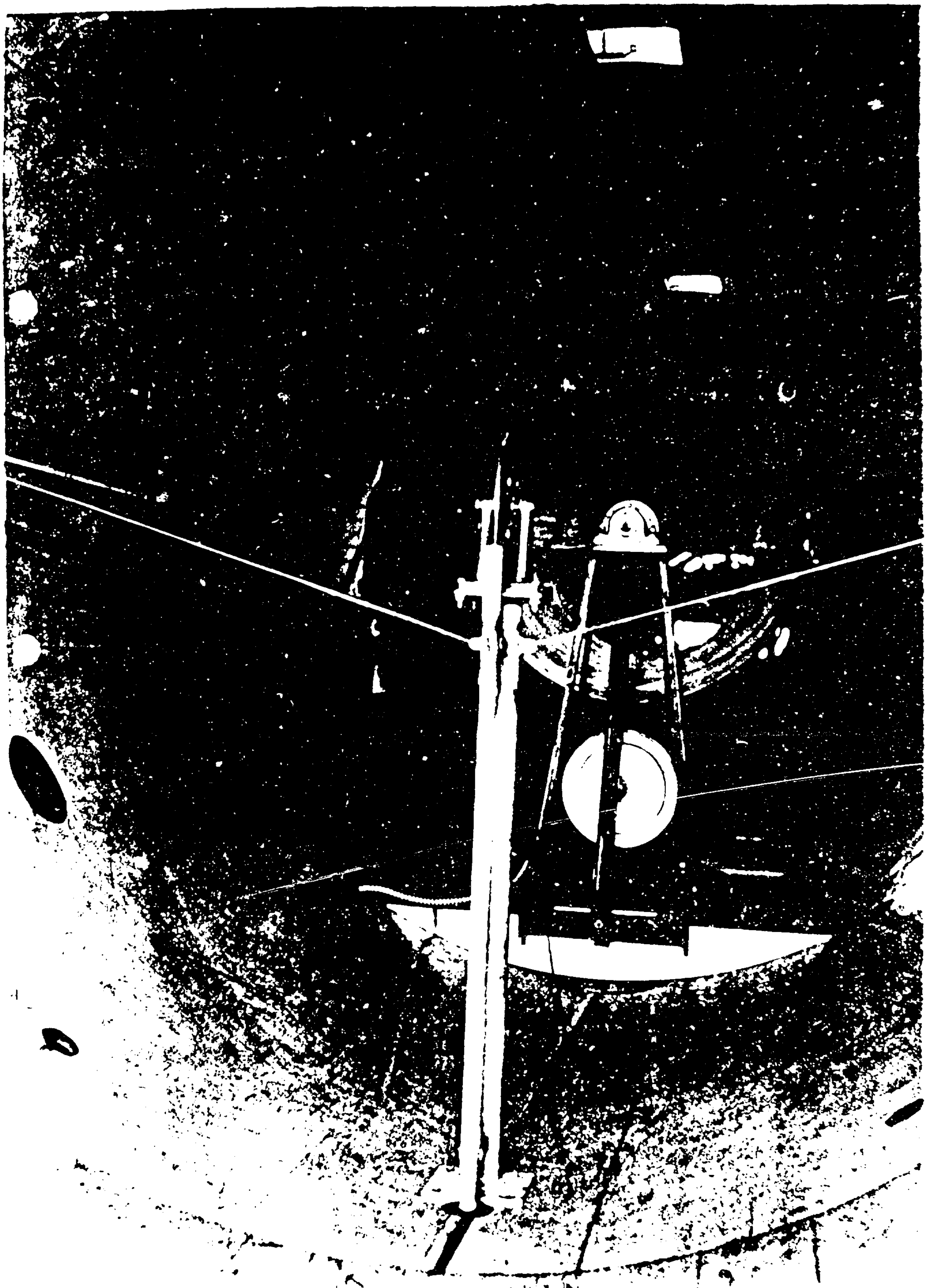

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